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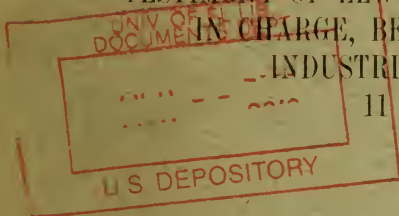
U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,

A. C. TRUE, Director.

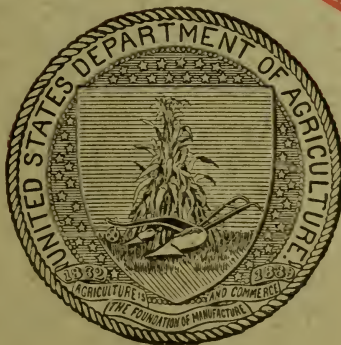
Irrigation Investigations, Elwood Mead, Expert in Charge.

IRRIGATION IN THE UNITED STATES.

TESTIMONY OF ELWOOD MEAD, IRRIGATION EXPERT
IN CHARGE, BEFORE THE UNITED STATES
INDUSTRIAL COMMISSION JUNE
11 AND 12, 1901.



REPRINTED FROM REPORT OF UNITED STATES INDUSTRIAL COMMISSION
ON AGRICULTURE AND AGRICULTURAL LABOR.



WASHINGTON:
GOVERNMENT PRINTING OFFICE,
1901.

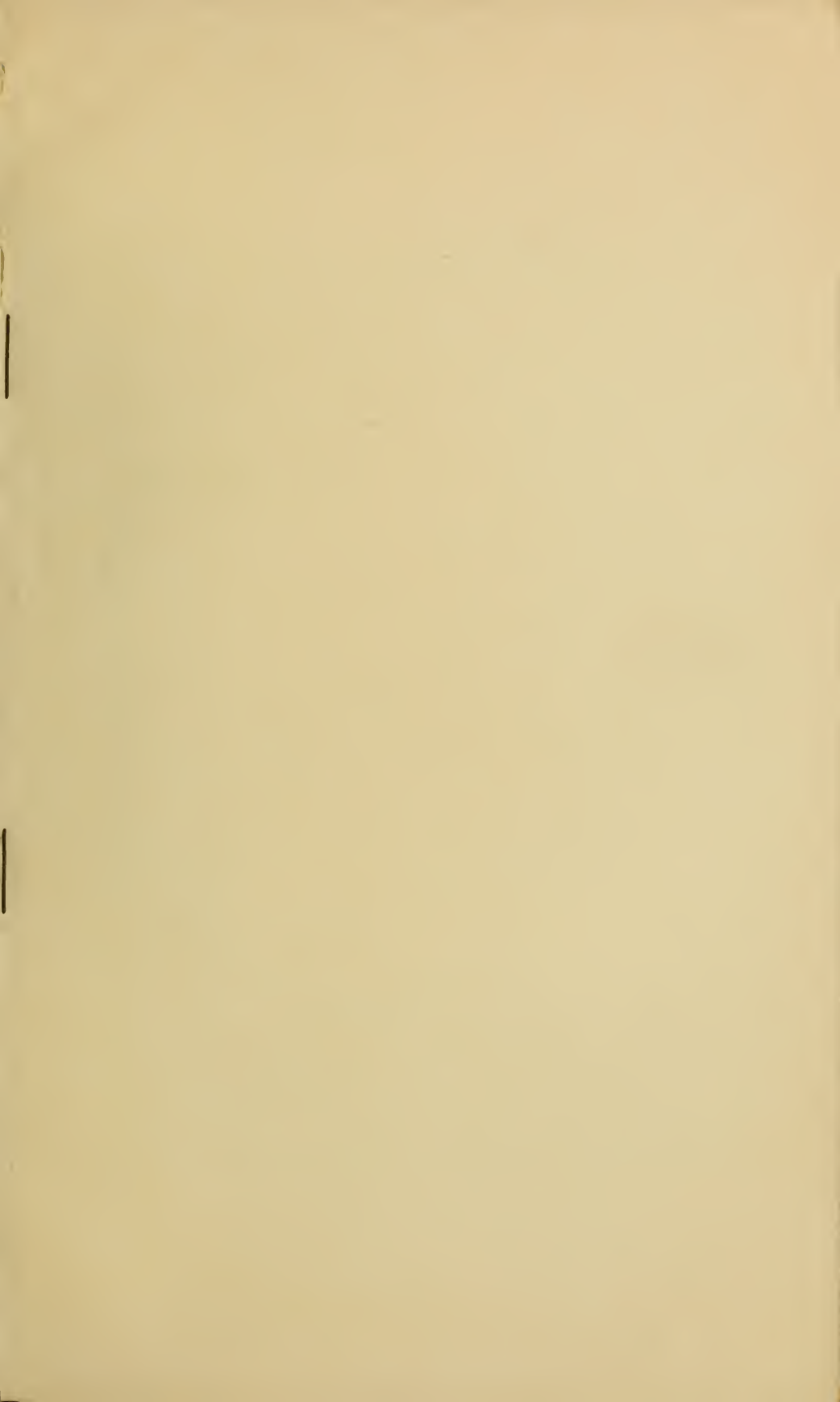
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- Bul. 86. The Use of Water in Irrigation. Report of investigations made in 1899, under the supervision of Elwood Mead, expert in charge, and C. T. Johnston, assistant. Pp. 253. Price, 30 cents.
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PARLEYS CREEK RESERVOIR, UTAH.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,

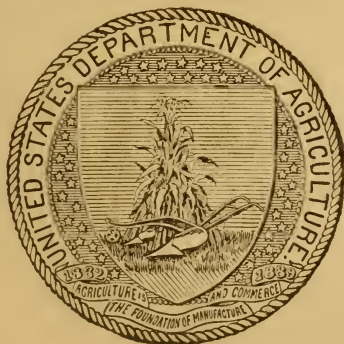
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GOVERNMENT PRINTING OFFICE.
1901.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., October 10, 1901.

SIR: I transmit herewith the testimony of Prof. Elwood Mead, expert in charge of the irrigation investigations of this Office, before the United States Industrial Commission. Professor Mead appeared before the commission June 11 and 12, 1901, to testify on the subject of irrigation in the United States. His testimony presents a review of the irrigation situation in the United States, including not only the arid region of the West, but also the humid sections of the South and East, where in two States alone more land has been brought under irrigation during the past five years than in any single State in the arid region during the same period. The testimony also deals briefly, but in some detail, with the practical aspects of extending public aid to irrigation, either through the State or national governments. The increased importance of the phases of the irrigation question discussed in the testimony as issues in both State and national legislation has created a considerable demand for information regarding them, and it is believed that the republication of the testimony will do much to supply the demand.

Respectfully,

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

	Page.
Introduction	5
Beginnings of irrigation in the United States	7
Importance of irrigation in the United States	7
Irrigation in the United States the result of private enterprise	8
Evolution of water laws in the arid region	10
Necessity for laws governing irrigation	10
Importance of water laws not at first appreciated	10
Control of streams left to States by National Government	11
Uncertainties of the water laws	12
The limitations of an appropriation	12
Conflicts between rights of appropriation and riparian rights	12
Establishment of titles to water	13
Colorado	13
Wyoming	14
Other States	14
Meaning of term "water right," and water-right contracts	15
Building of canals and distribution of water	16
Losses of water by seepage	17
Filling of canals by silt	21
Controversies over titles to water	22
Absence of public protection of water rights	22
Excessive appropriations of water	22
Principles governing water rights in Canada and Wyoming	25
Storage of water for irrigation	26
Reservoirs in the West private property	26
Storage makes public control necessary	27
Irrigation a State question	29
Leasing of the public grazing lands	30
National aid extended by land grants	31
Cost and value of irrigation	32
Products of the arid region	33
National aid for irrigation	35
Interstate water-right complications	37
Irrigation in the humid sections	38
Filling of reservoirs by silt	41
Appendix	43

ILLUSTRATIONS.

PLATES.

	Page.
PLATE I. Parleys Creek Reservoir, Utah	Frontispiece.
II. Fig. 1. Dam for the Otter Creek Canal, Utah	8
Fig. 2. Dam for the Beckwith Canal, Wyoming	8
Fig. 3. Dam for the Wyman and Irwin canals, Wyoming	8
Fig. 4. Dam for the Bear River Canal, Utah	8
III. Fig. 1. Head gate of the Consolidated Canal Company, Arizona ..	10
Fig. 2. Division gate of the Consolidated Canal Company, Arizona ..	10
IV. Map of a portion of the Cache la Poudre Valley, showing the exchange of water, Colorado	16
V. Fig. 1. Bear River Canal, looking north, showing drop	18
Fig. 2. Iron flume across Malad River, Bear River Canal	18
VI. Fig. 1. Appearance of irrigation canal when first completed	20
Fig. 2. Appearance of irrigation canal ten years after completion ..	20
VII. Fig. 1. The head gates of an Idaho Canal	24
Fig. 2. Side-hill construction on an Idaho Canal	24
Fig. 3. Irrigated farm in Idaho	24
VIII. Fig. 1. Head of Gage Canal, California	28
Fig. 2. Division bulkhead of Gage Canal, California	28
IX. Fig. 1. View of a stock ranch at Mesa, Ariz	32
Fig. 2. An almond orchard in Arizona	32
X. Artesian wells, head of Gage Canal, California	34
XI. Map of Bear River, showing location of ditches and irrigated land ..	38
XII. Fig. 1. Wasteway, Gageby Arroyo, Great Plains Water Company ..	40
Fig. 2. Outlet Conduit No. 2, Great Plains Water Company	40

TEXT FIGURE.

FIG. 1. Relation between the mean monthly discharge of the Poudre River and the appropriations therefrom	24
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IRRIGATION IN THE UNITED STATES.

INTRODUCTION.

On June 11, 1901, the United States Industrial Commission met at Washington, D. C., Vice-Chairman Phillips presiding. Mr. Elwood Mead, expert in charge of the Irrigation Investigations of the United States Department of Agriculture, appeared as a witness, and being duly sworn testified as follows:

Q. (By Mr. A. L. HARRIS.) You will please give your full name, post-office address, and your occupation.—A. Elwood Mead; I am irrigation expert in charge of the Irrigation Investigations of the Department of Agriculture.

Q. What State are you a native of?—A. Born in Indiana. For the past eighteen years I have lived in Colorado and Wyoming; for the past twelve years, Wyoming.

Q. How long have you made this subject of irrigation a study?—A. Eighteen years.

Q. How long have you been with the Agricultural Department?—A. Three years.

Q. Have you studied the subject of irrigation in connection with agriculture in the various States of the West, and I might say of the East also?—A. I have.

Q. Have you a written statement that you desire to present to the commission?—A. If you desire I will give an outline of my connection with irrigation. I went from Indiana to Colorado in 1882 to accept a professorship in the State Agricultural College. Four years later I became the professor of irrigation engineering in that college, being the first professor of this branch of engineering in this country. Between the time of going to Colorado and my acceptance of the last-named professorship, I was employed during two summer vacations by the State engineer of Colorado to make official measurements of the capacities of the irrigation ditches of the State having adjudicated rights to water. Colorado was the first of the arid States to assume public control over the diversion of water from streams. One of the first necessities of the legislation providing for this control was a table showing the capacities of the different ditches in use, and the measurements made to ascertain these capacities were the first of such measurements made. After two years of employment by the State

engineer during the summer months I became assistant State engineer, resigning from the college, but returning to it when a school of irrigation was created there. In 1888 I became Territorial engineer of Wyoming, and continued in that capacity and as State engineer after Wyoming became a State until 1898. In 1897 I became connected with the Irrigation Investigations of the Department of Agriculture, and for the past three years I have been in charge of these investigations.

Q. Have you written a number of reports that have been issued by the Agricultural Department?—A. Since coming to the Department I have had charge of the bulletins issued by the Department with reference to irrigation, of which the following is a list:

PUBLICATIONS OF THE OFFICE OF EXPERIMENT STATIONS ON IRRIGATION.

- Bul. 36: Notes on Irrigation in Connecticut and New Jersey. By C. S. Phelps, B. S., and Edward B. Voorhees, M. A. Pp. 64.
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- Bul. 138: Irrigation in Field and Garden. By E. J. Wickson. Pp. 40.

SEPARATES.

- Rise and Future of Irrigation in the United States. By Elwood Mead. Yearbook of Department of Agriculture for 1899. Pp. 25.
- Practical Irrigation. By C. T. Johnston, C. E., and J. D. Stannard. Yearbook of Department of Agriculture for 1900. Pp. 22.

BEGINNINGS OF IRRIGATION IN THE UNITED STATES.

Now, if the commission desires, I will take up and follow the general lines of the summary I sent you yesterday, and I will take up the questions that seem to me to be fundamental.

We are accustomed to think and speak of irrigation in the United States as being of recent development. Nothing could be further from the truth. In many parts of the Southwest, notably in northern New Mexico and Arizona, there are well-defined remains of irrigation works which have outlived by many centuries the civilization to which they belonged. Near Las Cruces, N. Mex., is an irrigation ditch which has an unbroken record of over three hundred years of service. The Spanish settlers along the Rio Grande were irrigating their gardens seventy years before the settlement at Jamestown. It is true, however, that irrigation by English-speaking people is only about 50 years old. For its beginnings we must go to Utah, where the little band of Mormon emigrants were compelled to adopt it to save themselves from starvation. It was twenty years after the beginnings in Utah that irrigation came to be an important factor in the growth and settlement of Colorado and California. It is an interesting fact that the earlier attempts in these two States where irrigation has assumed the greatest importance were made at the same time. The discovery of gold in California created the overland trail and opened the great interior valleys of the arid West to miners and stock raisers. At the stage stations bordering on streams and in the vicinity of mining camps men without any knowledge or experience built small, rude ditches and turned water on the thirsty soil. In every instance work was begun without apparent consideration of future necessities and by men to whom the whole subject was strange and new. It is only by understanding this lack of direction and the haphazard methods which prevailed in the beginnings of our age that we can understand the present situation.

IMPORTANCE OF IRRIGATION IN THE UNITED STATES.

There are few countries in which irrigation is destined to assume greater importance than in the United States. Throughout nearly all that portion of the country west of the one hundredth meridian successful agriculture is not possible without it, while each year sees an increase in its use east of that meridian. Leaving out of consideration Alaska and the recently acquired insular possessions, in some of which irrigation is already an important factor, the area of the United States east of the one hundredth meridian is 1,648,830 square miles. West of that meridian there are 1,433,849 square miles. Taking this meridian as an approximate division of the humid and arid portions of the United States, they stand in a ratio of about 53 to 47. The humid portion is, however, somewhat larger than this. There is a

narrow strip of well-watered territory along a part of the Pacific coast, and scattered throughout the arid region are relatively small areas with a rainfall considerably above that of the surrounding country, and where crops can be grown without irrigation. Making the one hundredth meridian the eastern boundary of the arid region is also purely arbitrary. The decrease in moisture begins 500 miles east of the Rocky Mountains, and gradually but irregularly increases as they are approached. Taking into consideration these minor modifications of the rough division changes the percentage of humid to arid land to a ratio of about 60 to 40.

Within the limits of the arid region it is not too much to say that irrigation is the basis of civilized life. In many of the arid States the value of the crops grown by irrigation exceeds the output of the mine or the profits of the factory. Not only is this true, but the cheap and abundant food supply which irrigation has provided has made possible the operation of many mines and the development of important industries which would have been impossible if the food supplies of their operatives had all to be shipped in from the farms of the humid East. The influence which irrigation has exerted in beautifying the landscapes of the watered areas of the arid West, in lessening the dust and discomfort, and rendering life more healthful and attractive, must not be lost sight of. The oases of fruit and foliage and the marvelous beauty of the gardens and orchards of southern California have done as much to fill the transcontinental trains from the East with health and pleasure seekers as has the healthful and enjoyable climate of that region. Nor does this statement apply to California any more than to the business centers of the other arid States. The cities of Phoenix, Reno, Boise, Salt Lake, and Denver are almost as much the creation of irrigation as the farms and orchards which surround them.

IRRIGATION IN THE UNITED STATES THE RESULT OF PRIVATE ENTERPRISE.

Irrigation in the United States differs from irrigation in nearly all other irrigated countries in one important particular. In Italy, France, Egypt, India, and even in Australia, many of the important irrigation works have been built by the Government and owned and protected as public works. In the United States, on the other hand, every canal in operation and, with one or two exceptions, every reservoir used in irrigation, is owned and protected as private works. Neither the several States nor the General Government have as yet entered into the work of ditch or reservoir building. Colorado has built two or three reservoirs with State funds and begun one canal, but, outside of this, investments of \$200,000,000 or more to provide water for the cultivated lands of the arid West have come from private funds. Whatever has been done in the way of overcoming physical obstacles,

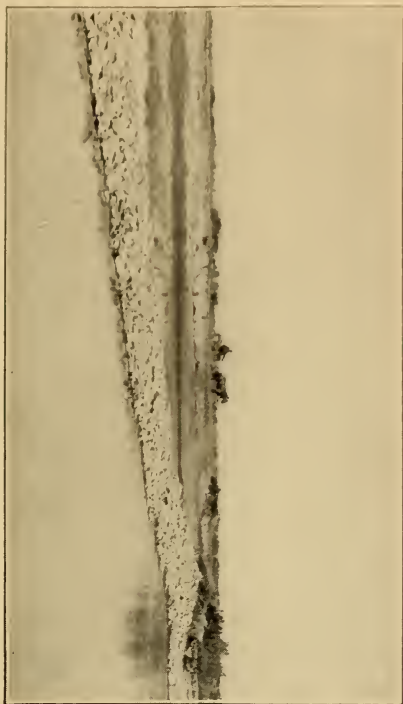


FIG. 1.—DAM FOR THE OTTER CREEK CANAL, UTAH.



FIG. 2.—DAM FOR THE BECKWITH CANAL, WYOMING.

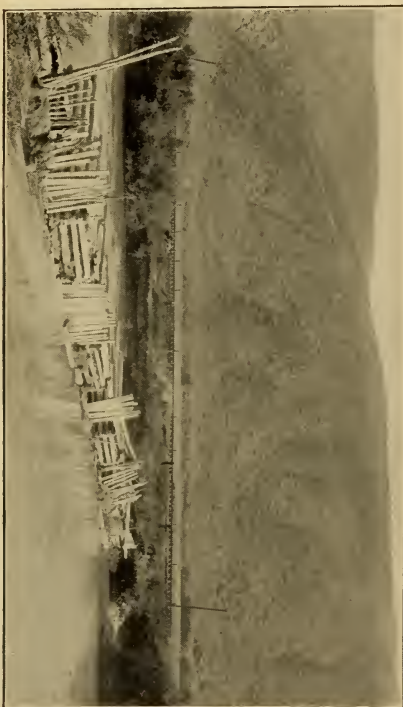


FIG. 3.—DAM FOR THE WYMAN AND IRWIN CANALS, WYOMING.

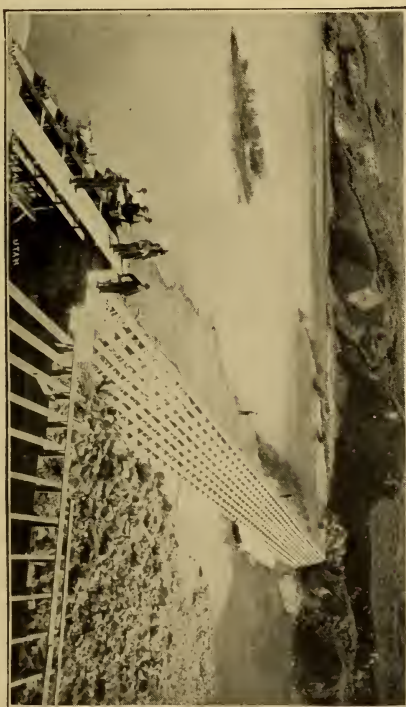


FIG. 4.—DAM FOR BEAR RIVER CANAL, UTAH.



the building of dams to control mountain torrents, the aqueducts which follow the precipitous sides of mountain canyons, the thousands of smaller ditches, and the hundreds of important canals, together with the immense outlay of money and toil required to put arid land in condition for the distribution of water, have all come as the result of the outlay and effort of individual companies and corporations.

Owing to the fact that this development has been left to private enterprise, there has been a delay in the enactment of laws required to protect irrigation investments and to secure to the water user his proper share of the stream along which he lives. In countries where canals are built with public funds, adequate laws for governing the division of a stream which fills them receive early attention, and the leading consideration in the location of these public works is a conservation of the water supply and its use on the best land. In the United States, on the contrary, the building of ditches and the reclaiming of land being a private matter, public considerations have received but little attention in the location of works or in the enactment of laws to determine rights to streams. The amount of money which the individual company projecting irrigation works had was the controlling consideration in the location of canals and ditches. As a rule, the places where ditches could be built at the least cost were first selected. Where these favorable locations have been utilized, larger and costlier works have been undertaken; and after the natural flow of streams has been absorbed, there has followed a natural construction of reservoirs to store the flood waters and the waters which run to waste during the season when water is not required in irrigation. In States having a favorable climate, like California, or people of exceptional enterprise, as in Colorado, or where there has been from the first a large local demand for farm products, owing to the proximity of mines, irrigation has developed more rapidly than in States where the demand for irrigated products or the price received for them has not been so favorable. Utah has more cultivated land than Montana, although the area susceptible of irrigation in Montana is many times that of Utah.

It is probable that if canals had been built as public works the leading consideration would have been an abundance of water supply, but being private works the leading consideration has been the cheapness with which ditches could be built and the profit with which the rights in these ditches could be disposed of. Because of this there are many streams in the West where the natural flow has already been fully utilized. The ditches and canals which take water from the Arkansas River in Colorado and Kansas cover more land than the stream can be made to irrigate if every available reservoir site along the stream is improved, and all the water which can be is utilized. The canals which divert the South Platte River in Colorado and Nebraska cover all the land which that stream can be made to irri-

gate. On hundreds of streams in the various arid States and Territories the capacity of the canals and ditches already built is fully equal to the water supply. In some cases there are more ditches than can be filled, and the people who depend on them suffer from drought as severely as do the people who depend on rain. As a rule, all the land which can be cheaply irrigated is now either being irrigated or is owned by parties who intend to irrigate it, and the streams which can be easily diverted will require reservoirs to make a further extension of the cultivated area safe and profitable; nevertheless there is a large field for future development. The larger rivers of the arid region, like the Missouri, Big Horn, Snake, Rio Grande, Green, and Sacramento, are as yet almost undiminished in flow. The reason for this is that the cost of works to utilize them has been too great. In many cases this cost will for years to come be beyond the reach of private enterprise or beyond the hope of any profitable return if undertaken as private enterprises, and this is one of the reasons why State or national aid is regarded as a necessity, or, if not a necessity, as a wise public policy for the country to adopt.

EVOLUTION OF WATER LAWS IN THE ARID REGION.

NECESSITY FOR LAWS GOVERNING IRRIGATION.

Wherever irrigation is necessary, laws for the regulation and control of streams must be enacted if development is to be peaceful and prosperous. It is just as necessary for the farmer to know who owns the water he uses as it is for him to know that he has title to the land that he cultivates. In the arid region of the United States the character of titles to water has an especial importance, because of the scarcity of the supply. With very few exceptions, there is more irrigable land along the river than the stream will serve. Hence whoever controls the stream practically controls the land on which it is used, because he can dictate what land shall be made productive and what land must remain forever arid and almost worthless.

IMPORTANCE OF WATER LAWS NOT AT FIRST APPRECIATED.

The importance of adequate water laws was not appreciated at the outset. There were many reasons for this. In the beginning nearly everyone's attention was given to the overcoming of physical obstacles. The Mormons at City Creek, in Utah, could not wait for the passage of irrigation laws. They had to divert and use the stream to keep from starving to death. The settlers at Greeley, Colo., had first of all to learn how to build and operate ditches. With their settlement came the grasshopper plague, and between this and the contest with breaking ditches, the improvement of fields, and the raising of money to make needed repairs and improvements, it was nine years before they began to study seriously how they were to protect their right to take water. In California millions of dollars had

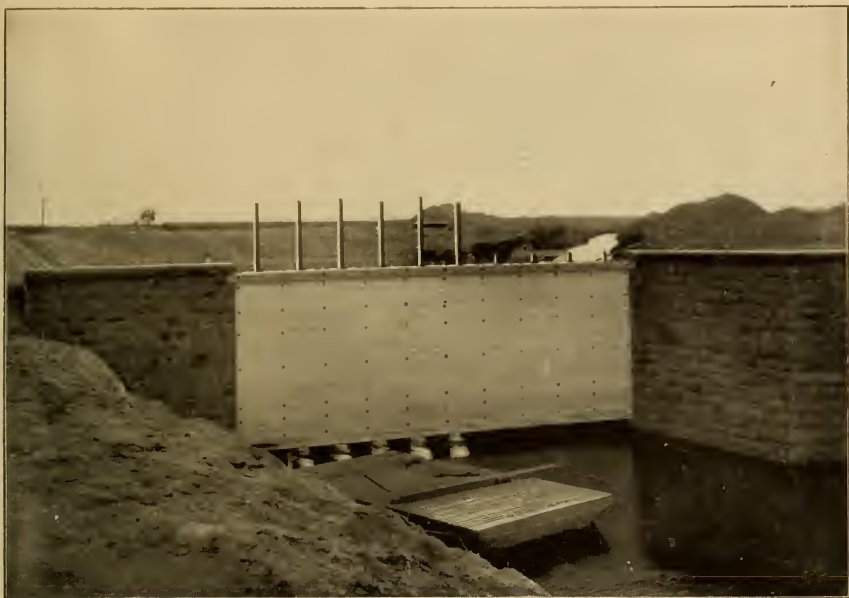
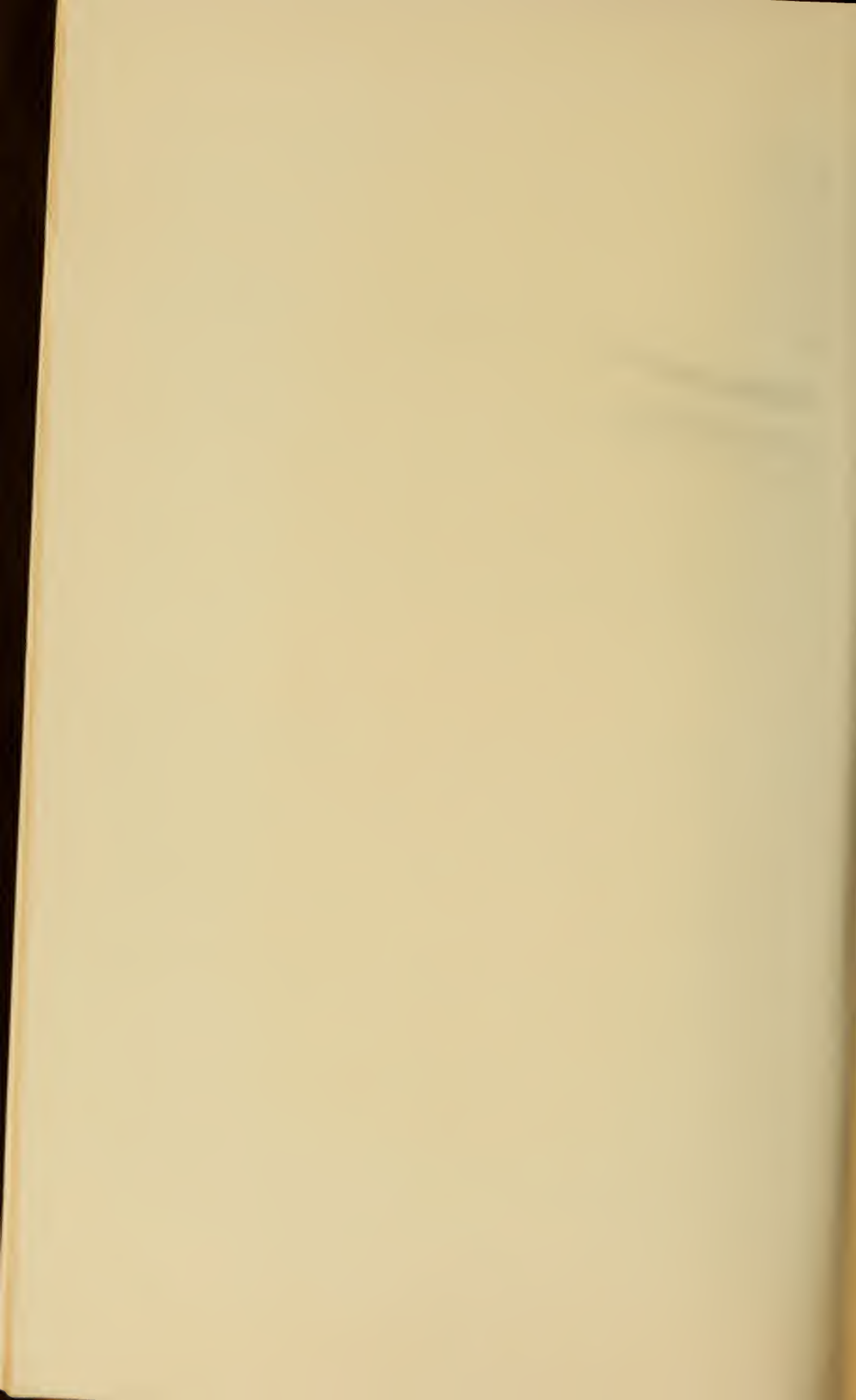


FIG. 1.—HEADGATE OF THE CONSOLIDATED CANAL COMPANY, ARIZONA.



FIG. 2.—DIVISION GATE OF THE CONSOLIDATED CANAL COMPANY, ARIZONA.



been invested in canals before the controversy arose over riparian rights.

There are other reasons for the delay in providing adequate laws for the protection of irrigators' rights to water. Many of the States interested in irrigation lie partly within the arid and partly within the humid region. In every case the humid portions were first settled, and the first inhabitants framed the earlier laws. The importance of irrigation was not realized and no provision made for its future development. In many of the arid States mining and the range-stock industries preceded irrigation, and the men engaged in these industries, together with the people in the cities, framed the earlier laws. Even among irrigators themselves it was a long time before the difference between the institutions of arid and humid lands was realized. The prevailing idea of everybody in the early settlement was that they were to create communities which would be the counterparts of those they had left in the East. Although they realized the importance of water and their dependence on the stream which irrigated their farms, the early settlers as a rule opposed any legislation which would restrict or define their rights or which would make rivers public property and provide for their orderly and systematic disposal, as is done with public land. It was not until the increased use and growing scarcity of water began to rob some of the lower ditches along streams that any headway could be made in overcoming this opposition and indifference through needed legislation. But as ditches multiplied it began to be seen that when the demand for water was greater than the supply those at the head of a stream could take all the water there was, while those lower down, unless protected by law, must see their fields parch and their crops wither whenever the stream ran low. It was the fact that the ditches of the Greeley colony were on the lower end of the stream which furnished their water supply, and that they were robbed by ditches built later, but located farther up the stream.

In the early days of Utah there was no need of any legislation, because the people were all practically of one faith and their religious advisers were also their directors in temporal affairs, which included among other things the settlement of quarrels over water. But in recent years litigation has been a conspicuous feature of irrigation development in Utah, and no State has a greater need of an enlightened code of water laws.

CONTROL OF STREAMS LEFT TO STATES BY NATIONAL GOVERNMENT.

Without going into the details of the evolution of water laws in the different States, it may be said that each State and Territory of the arid regions has enacted more or less legislation governing the use of water in irrigation, and in each of the States the statute law has been supplemented by numerous and important court decisions.

Whatever control is exercised at the present time is exercised by the States and Territories and not by the General Government. The latter in 1866 passed a law recognizing local laws and customs with relation to mining and irrigation, and since that time has not interfered with the enactment or enforcement of whatever system the States and Territories have seen fit to adopt. The situation thus created is of the highest significance in determining what the Government ought to do in the future and its importance ought always to be recognized.

UNCERTAINTIES OF THE WATER LAWS.

THE LIMITATIONS OF AN APPROPRIATION.

The laws and decisions of the States and Territories have apparently settled certain issues with respect to the use of streams in irrigation, while others equally important are as yet involved in doubt and controversy. One of the issues settled is that the first appropriator from a stream has the first right to its water, and that the rights of subsequent appropriators follow in order. Another doctrine almost universally recognized, in theory if not in practice, is that all rights must be based on the actual beneficial use of the water. Among the questions in dispute, the limitations of an appropriation take first rank, and about this there is wide difference of opinion and of law. In some States and Territories water is regarded as personal property. The owner of it can rent it or sell it just as he would a horse or a cow. His appropriation is not attached to any particular tract of land, nor to the ditch through which it was nominally first diverted. In some States water rights are held to be attached to the land, and the volume of the appropriations is limited to the necessities of the land.

The conflicting views regarding the nature of a water right are largely due to the different methods employed in constructing ditches. Where ditches are small and the same individual owns the land on which the water is used and the ditch which diverts it, the tendency is to favor the union of land and water. But on many streams corporations have built large and costly works in advance of settlement to supply lands they did not own and never expected to own. Under such conditions the natural tendency has been to favor a doctrine which would make the owners of the works the appropriators of the stream and to give them the greatest possible freedom in disposing of the water supply to users when the lands below the canal were brought under cultivation.

CONFLICT BETWEEN RIGHTS OF APPROPRIATION AND RIPARIAN RIGHTS.

Another troublesome problem in many of the Western States has grown out of the conflict between the rights of appropriators of water under State laws and the rights of riparian proprietors, as recognized by State constitutions. In Colorado, Wyoming, Montana, Idaho,

Utah, Nevada, and in the Territories of New Mexico and Arizona, riparian rights have been abrogated, but in California, Washington, Oregon, the two Dakotas, and Nebraska the constitution recognizes the common-law doctrine of riparian rights, which requires that streams must flow undiminished in volume. These States have since passed laws which permit irrigators to appropriate and divert the entire supply until it is an open question which of these two conflicting policies prevails. It will hardly be wise for either the State or the General Government to extend any considerable aid while whatever is done by private enterprise will be attended by so much hazard as to make development comparatively slow and uncertain.

For several years past none of the arid States has had a more rapid growth than Nebraska. Many large canals have been built, and a large acreage of land in the western part of the State brought under cultivation. This was due in part to favoring natural conditions, but more largely to a very excellent law providing for the systematic recording of water appropriators' rights and their legal recognition when the water had been used. All this has been changed by a recent decision of the supreme court, declaring the common-law doctrine of riparian rights to be the law in that State. If this is true, then every diversion of water is illegal. No one knows what is to be the result. Irrigators are fearful and investors in canals greatly alarmed. There seems to be reason for this feeling, as the millers of Nebraska, some fifty in number, at their meeting last week, perfected an organization under which they are to institute lawsuits to enforce the recent decision of the supreme court, and close up the irrigation canals that are depleting the streams.

In Kansas the statute law recognizes the doctrine of riparian rights east of the ninety-seventh meridian, and the doctrine of appropriation west of it. This seems to be a sensible arrangement, although it sounds rather arbitrary to say that west of an imaginary line all the water of a river may be used, while a few feet away to the east of it none may be diverted.

ESTABLISHMENT OF TITLES TO WATER.

COLORADO.

Next in importance to the nature of a water right is the method by which it is established. To Colorado is entitled the credit of passing the first law on this subject. It gives to each claimant of water the right to inaugurate in court a procedure under which all claimants to the same supply can be compelled to come into court and have the relative priorities and amounts adjudicated. After this has been done the Colorado law provides that the streams shall be under public control, and the State officer known as a water commissioner shall in times of scarcity divide the water among the holders of these adjudicated rights.

WYOMING.

It can scarcely be doubted that there should have been provided at the outset some orderly tribunal which would have managed and disposed of the water of streams, as the General Government has surveyed, cared for, and disposed of the public lands. If that had been done, records of claims and appropriations would have been complete and accurate, and the danger which now threatens us of excessive and speculative appropriations would have been averted without injury to anyone, and with less cost in administration than has been necessary to carry on the litigation in the courts. The experience of Wyoming with such a tribunal has fully supported this conclusion. In Wyoming the waters of streams are public property. This property is managed by special tribunal. Every intending user of water must secure from this tribunal a permit. Where all of the water of a stream is appropriated, permits are refused, because additional ditches would not mean the cultivation of more land, while they might mean controversy with other ditches or the lessening of the rightful water supply of prior appropriators. This law has been in force for ten years. Under it the rights of over 4,000 appropriators have been established without litigation or controversy, and these rights are recognized as having nearly the same stability as patents to public land.

OTHER STATES.

In many of the States and Territories there is no orderly procedure for the settlement of the rights of all irrigators to a stream at one time. In these States, whenever the ditches at the head of a stream rob the ditches below, controversies are sure to arise. If the irrigators below are lawless or impulsive, raids to tear out the dams and headgates above are likely to result. But among law-abiding water users the only remedy is an appeal to the courts, which stand as the sole tribunal between injustice and violence. The objection to this court litigation is that it is exceedingly costly and apparently unending. A lawsuit of one ditch owner against another may settle the issues between those two parties, but it can not be made to apply to the ditch owners and irrigators not made a party to the suit. It too often happens, therefore, that litigation, instead of settling controversies, only serves to create new issues, which, in turn, have to be litigated. In one case in California "A" brought suit against "B," and was decreed to have the first right to the water of a stream. "B" then brought suit against "C," and was declared to have a better right than "C." Then "C" saw there were superior rights to his, and he made adequate preparation and gathered his witnesses and all the information he could and brought suit against "A," while "A," relying upon the fact that there had been a judgment in his favor already, put up a weak defense, and "C" was decreed to have a superior right

to "A," and "A" was enjoined from interfering with "C's" use of the river, and all parties were back at the beginning again. That is not an isolated instance; on the contrary, it is a typical instance of the litigation over water.

MEANING OF TERM "WATER RIGHT" AND WATER-RIGHT CONTRACTS.

This is a brief and imperfect outline of the methods by which the streams used in irrigation have been appropriated and the rights to their waters established; but the term "water right" has also another meaning. Many of the appropriations to large ditches and canals carry volumes of water sufficient to irrigate anywhere from 100 to 500 farms. The owners of farms along these canals purchase from the holder of the appropriation what is also called a water right. The limitations of the water right of the canal owner are fixed by law, while the limitations of the water right of the irrigator are fixed by the terms of his contract with the canal owner. As a rule, the two water rights have no resemblance to each other. The right of the canal owner gives him a continuous flow of the volume appropriated, with the right to dispose of it to whomsoever he pleases, and with no restrictions as to the means of diversion or place of use. The water-right contract under which irrigators usually obtain their supply only gives them a right to water during the irrigation season. This right is not to a continuous flow, but is to vary with the irrigators' necessities. Instead of the place of diversion and use being unrestricted, both are defined in the contract. If the commission desires it, I will submit a number of blank water-right contracts of the form used by ditch companies in disposing of water for irrigation, as they illustrate the conditions which govern the growing commerce in water.

Q. (By Mr. PHILLIPS.) Are there different contracts in different States?—A. Yes; the Irrigation Investigation of the Department of Agriculture has about 500 of these contracts altogether.

Q. All different kinds of contracts?—A. They are all contracts of different companies, but a majority of them are essentially alike in their conditions. Out of this collection I will submit to you a half dozen or more. These contracts fix the conditions of the traffic in water, the conditions on which the users receive it, and its value. Decrees give the water to the canals, and the canals sell the water represented by those decrees. Some of the contracts are of a dual nature; they provide a charge for the right to the water itself, and also a charge for the service rendered in the delivery of the water by the company. Some of them are of a character that contemplates the eventual transfer of the works and of the appropriation to the purchasers of these contracts. Now, I will give some details regarding the prices of water rights. I will submit as samples of water-right

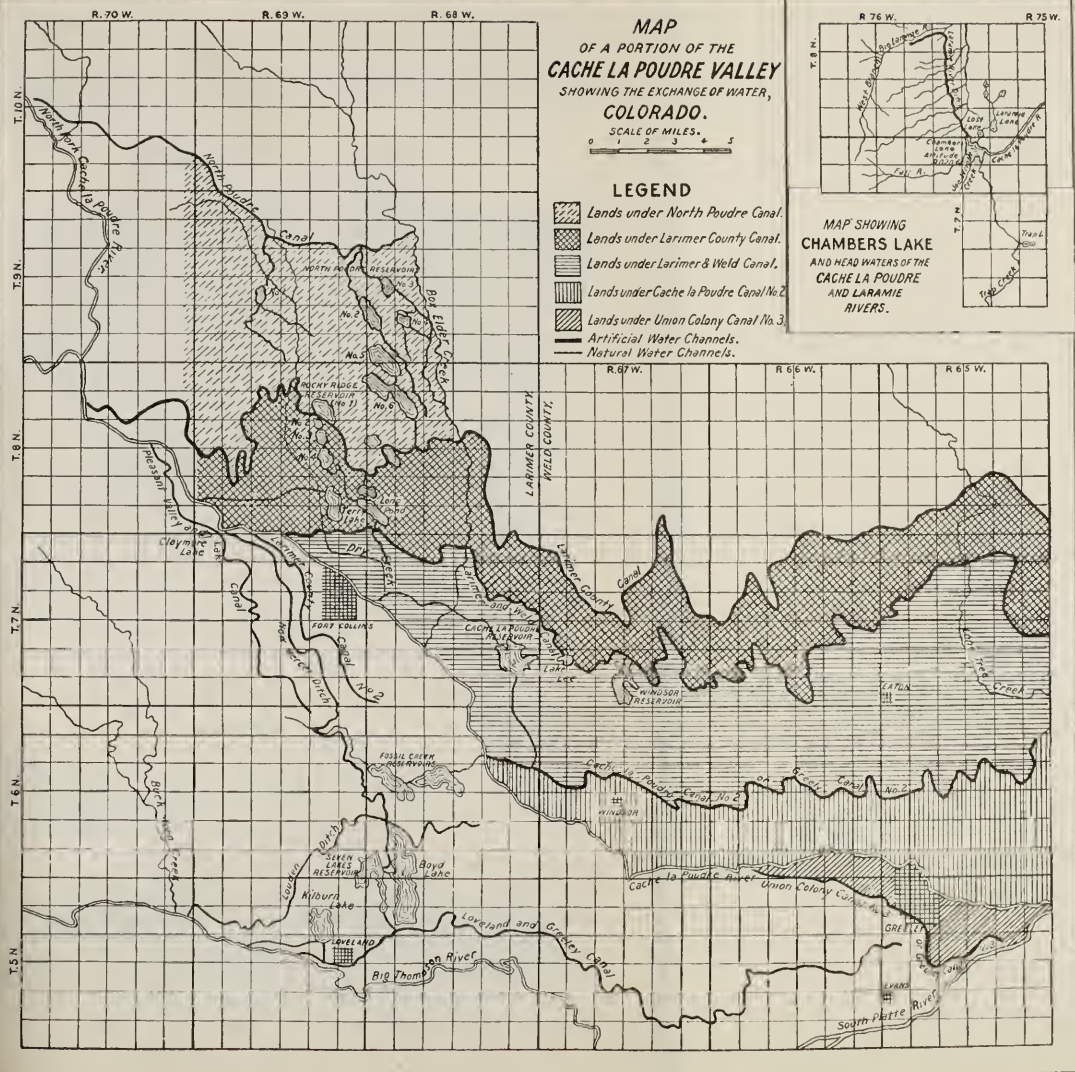
contracts, three from Colorado, one from California, and one from New Mexico.¹

BUILDING OF CANALS AND DISTRIBUTION OF WATER.

Q. (By Mr. LITCHMAN.) We would like some description at some point in your statement of the manner of constructing these ditches.—
A. Permit me to submit the map in Bulletin 92, showing the canals taking water from the Poudre River, in Colorado. It will be seen by examining this map that each of these ditches receives water from the stream and in this way covers a considerable area of land between the canal and the river or between it and the canal next below. This is made possible by the topography of the country. The map shows a canal system east of the Rocky Mountains. From the eastern base of this range for nearly 500 miles the country has a slope varying from 25 feet to the mile near the foothills to 4 or 5 feet to the mile as it nears the Missouri River. Denver has an elevation of 5,250 feet above sea level. Omaha is nearly 4,000 feet lower. The intervening country is so free from hills or broken and irregular slopes that it would be possible to build a canal to reach from one city to the other and to water the intervening country, if there were water enough to supply it. In a general way the country slopes away from the base of the mountains, and canals can be built to take water from the streams as they flow away from the mountains and distribute it by gravity over all of the country suited to irrigation. Bear River, in Utah, for a mile below the head of the Bear River Canal, has a fall of 120 feet. The canal in that distance has a fall of 4 feet. Hence the bed of the canal is 116 feet above the stream at the end of that distance, a sufficient elevation to permit of the watering of the plateau, embracing nearly 100,000 acres of land. The river shown in the map (the Poudre) has a fall of 25 feet to the mile; the canals shown have each a fall of about 2 feet to the mile, so that for each mile of canal through which the water passes there is a gain of 20 feet or more in elevation above the river. In using the water it is turned from these canals and ditches on the lower side and distributed by gravity over the fields below. The methods of distribution vary with different crops and in different sections of the country. Where crops are cultivated water is run down furrows. Furrow irrigation is now the method generally employed in the irrigation of orchards. Small grain and native and cultivated hay are usually irrigated by flooding, which means that the water is spread over the entire surface.

The map of the canals taking water from the Poudre shows by the different shading the area irrigated by each. The first of the larger ditches to be built has its irrigated area indicated by diagonal lines; the next is on the opposite side of the river. These two are the

¹ The contracts referred to are on file with the Industrial Commission. Two typical contracts are set out in full in the Appendix hereto.



MAP OF A PORTION OF THE CACHE LA POUDE VALLEY (SHOWING THE EXCHANGE OF WATER), COLORADO.



COLUMBIA

UNIVERSITY

OF CHICAGO

PRESS

1910

1911

1912

1913

1914

1915

1916

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1918

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1932

1933

1934

1935

Greeley Colony canals, and they were built at the lower end of the stream because there were fewer obstacles there. Later the canals farther up the stream were built, and as they took more and more water from the stream they lessened the supply which ran down to the older ditches below. (See Pl. IV.)

LOSSES OF WATER BY SEEPAGE.

In all of the West except southern California irrigation ditches and canals are unlined. The soil over which the water passes is expected to retain it in its channel; but there are cases where it fails to do this and the losses from seepage and percolation are excessive. Where canals cross strata of coarse gravel, or where there are gypsum deposits, the losses from this cause are very great. In one instance the measurements of the Irrigation Investigation of the Agricultural Department showed a loss in a canal of 75 per cent of its entire supply in a distance of less than a mile. The following, taken from the report of these investigations for 1899,¹ shows the extent and character of these losses over a widely distributed area:

In practice the losses in canals from percolation, leakage of flumes, evaporation, etc., are an important factor in fixing the average duty of water from a river or an extensive canal system. To determine this average duty the volume should be measured at the headgate, and the acres it irrigates is the duty which canal managers have to consider in determining the area their works will irrigate. This duty is much lower than that obtained by measurements made on laterals or at the margins of the fields where used, the influence of the losses between the headgate and the heads of laterals being greater than has usually been supposed. Where canals cross gravel beds or gypsum deposits the results closely resemble trying to carry water in a sieve. The following table gives the number of acre-feet used in the irrigation of an acre of land where the measurements were made at the canal headgates, and include the loss from seepage and evaporation:

Duty of water when losses in main canals are included.

Name of canal.	Acre-feet.
Pecos Canal, New Mexico	6.61
Mesa Canal, Arizona	3.81
Butler Ditch, Utah	6.24
Brown and Sanford Ditch Utah	5.22
Upper Canal, Utah	6.30
Amity Canal, Colorado	4.92
Rust Lateral, Idaho	5.06
Average	5.47

A comparison of the duties in the above table with those obtained when the water was measured where used will show that more than twice as many acre-feet were required where the water was measured at the headgate as where measured at the place of use; or, in other words, the losses in the canals from seepage and evaporation amount to more than one-half the entire supply. This is in accord with many of the measurements made on irrigation canals in India. Among those

¹ U. S. Dept. Agr., Office of Experiment Stations Bul. 86, pp. 35-39.

recorded in Buckley's Irrigation Works in India is one which shows that the irrigation of wheat under the Jamda Canal, in Bombay, required 5.6 acre-feet of water for each acre irrigated where the water was measured at the head of the canal, but where the water was measured at the place of use it required, in two experiments, only 2.1 acre-feet and 1.4 acre-feet to irrigate an acre, the loss in the canal being more than 50 per cent. On the Hathmati Canal, in the same country, the loss from the seepage and evaporation was 50 per cent. These losses in transit are much heavier than is the rule on the older canals of India, and are doubtless more general than they will be in this country when the banks of canals are older and when they are operated with greater regard for economy.

The report of Mr. Reed shows that 47.7 per cent of the water turned in at the head of the Pecos Canal reached the consumers, while 52.3 per cent was lost through seepage and evaporation. The causes of this loss are explained to be the checking of the velocity in the canal by dams in order to throw water on ground too high to be irrigated without this, certain defects in construction, and the nature of the soil in which the canal is built. The canal has a bank on one side only. This has produced stagnant lakes and pools on the upper side wherever the canal crosses ravines, or where the ground on the upper side is so low that the water overflows it when the canal is filled. Mr. Reed's report also shows the variation in rate of seepage due to the character of the soil, three-fourths of the water entering one section of the canal 1 mile long being lost. To his summary of the causes of the great loss of water there may be added the fact that the water used in this canal is taken from the reservoirs. Its temperature is already above that of most mountain streams, which facilitates alike its rapid filtration and evaporation. It is perfectly clear, owing to the fact that all of the sediment carried by the river is deposited in the reservoirs. This canal affords an illustration of a lower duty on a particular farm, measuring the water at its margin, than the average under the main canal, measuring the water near the headgates. Mr. Reed points out the causes for this, and shows that it does not illustrate the necessities of irrigation, but the possibilities of waste under encouraging conditions.

The water taken into the Mesa Canal during the four years that measurements have been made has varied from enough to cover land to a depth of 5.9 feet in 1896 to 3.8 feet in 1899. A measurement was made in 1899 of the water used on a farm where the land had not before been irrigated, and where more than the average amount of water was required. Owing to the fact that rotation was practiced on the lateral leading to this farm, it is impossible to determine the exact quantity lost in passing through it, but the water delivered at its head for this farm would have covered the land to a depth of only 2.8 feet. The difference between the average depth under the main canal and the depth of water used on this farm was just 1 foot, or a difference in quantity of 1 acre-foot per acre irrigated. Mr. Code estimates that this difference would have been much larger if the loss in transit through the lateral had been determined. As it is, this shows a loss of over 25 per cent.

The construction of the Gage Canal is such as to make losses through seepage practically nothing, owing to the canal being cemented. The loss from evaporation is also small, because the canal is deep and narrow and has throughout its length a uniform cross section, with no pools of still water on the upper side. As compared to losses varying from 25 to 75 per cent shown in other canals, the loss of only 6 per cent in this canal has great significance. The water turned into the head would have served to cover the land irrigated to a depth of 2.24 feet, while the mean depth for the water delivered to irrigators' laterals was 2.11 feet, a loss of only 0.13 of an acre-foot per acre irrigated. Canals can only be cemented on earth, as is done in California, in localities where frosts in winter are not severe.



FIG. 1.—BEAR RIVER CANAL, LOOKING NORTH, SHOWING DROP.



FIG. 2.—IRON FLUME ACROSS MALAD RIVER, BEAR RIVER CANAL.



There are other remedial measures which can be employed in other sections which will, no doubt, be largely adopted when the extent of the loss from this source is more generally realized. Dumping clay into the canal and causing it to be distributed by agitating the water has been tried with good results on some Nebraska ditches.

The report of the careful and interesting investigations of Professor Fortier at the Montana Agricultural Experiment Station shows that in the Middle Creek Canal nearly 22 per cent of the total flow was lost in seepage in the first 4 miles, while the probable loss in the entire canal was 35 per cent. The conclusions of Professor Fortier are in accord with those of other observers as to both the evils resulting from this loss and the methods by which it may be reduced.

The water taken into Logan and Richmond Canal would cover the entire area it irrigates to a depth of 3.59 feet. The water actually used on the Cronquist farm would have covered it to a depth of only 2.6 feet, the difference between the average duty under the canal and the measured duty on one farm under it being nearly 1 acre-foot of water for each acre irrigated, or a difference of about 28 per cent. It is believed that this can be fairly taken as the loss resulting from the seepage and evaporation in carriage.

The water entering the headgate of the Amity Canal in Colorado would have served to cover all the land irrigated to a depth of 4.92 feet. The water delivered from the Biles Lateral would have covered the land under that lateral to a depth of only 1.82 feet. The difference between the average duty under the canal and the special duty under one lateral is 63 per cent. This seems to indicate that more than one-half of the water taken from the river disappears before it reaches the place of use. An examination of the map of the Amity Canal will show the reason for this excessive loss. The canal is a large, long one and much of the time last season was only partly filled. More than one-half of the time the water flowing through it was spread out in a broad, thin sheet, which reduced its velocity and gave abundant opportunity for the continuous sunshine to raise the temperature. This increase in temperature facilitated both its disappearance in the air and its filtration through the soil. Mr. Berry's report shows that the season of 1899 was unusually windy, making evaporation greater than usual.

Enough water was taken into Canal No. 2 at Wheatland, Wyo., to have covered all the land irrigated to a depth of 2.53 feet, while only enough water was delivered through the J lateral of that canal to cover the two fields on which the water used in irrigation was measured to a depth respectively of 0.7 and 1.55 feet, the apparent loss in the canal being one-half the water entering it. In this case this high rate of loss is what might have been expected. The canal is long. It traverses a steep hill-side slope for 2 miles, in which distance the loss under the lower bank is excessive. In many places the bottom is gravel, through which water escapes freely.

In order to more carefully study the variations in these losses, arrangements were made early last season by Frank C. Kelsey, city engineer of Salt Lake City, Utah, to measure the seepage loss from the Jordan and Salt Lake Canal from the Jordan River. This canal is 29 miles long, with a bottom width of 20 feet. It originally had a grade of 2 feet per mile, but when measured was in bad condition, with a flow of 30 cubic feet per second at the head. The loss in 29 miles was 45 per cent.

The losses from seepage in new canals are excessive. For the past six months 500 inches of water have been flowing in at the head of a 10-mile lateral built at Billings, Mont., in 1899, but as yet not a drop has reached the lower end. On a canal built in Salt River Valley, Wyoming, there was a loss, in 1896, of 10 cubic feet per second in a distance of 100 feet, which continued for several weeks with no apparent prospect of the loss diminishing. This was about one-third of the canal's flow. The canal was then abandoned. The canals which take water from the North Platte River are all subject to excessive losses when first built, because

of the sandy soil through which they must pass. In high water, however, this river is heavily charged with a white clay, due to the erosion of its banks. When this is deposited on the sides and bottom of ditches it forms a coating only less impervious than cement, and after a few weeks' operation during high water seepage losses always show great diminution.

Mr. Code reports that the water of Salt River, Arizona, contains a cementing material which in time renders its banks almost water-tight, so long as they remain undisturbed. This has not heretofore been possible on the Mesa Canal, because it has been undergoing constant repairs and improvements.

Q. (By Mr. A. L. HARRIS.) Does that seepage come to the surface below on ground that may be used for crops?—A. Yes. The loss of water by seepage is not only a serious problem with canal owners, but frequently becomes the cause of grave injury to the farming lands below. The water which escapes through the bottom of the canal follows the path of least resistance, and this sometimes takes it into the channel of the river or causes the appearance of springs in ravines which before were dry, or it may lead it to reappear in the fields below, often converting them into marshes and swamps. Instances are not infrequent where thousands of acres of land have for a time been rendered valueless from this cause. The saturation of the subsoil and the gradual rise of the water level nearly always attend irrigation. The first wells dug in the San Joaquin Valley in California were 60 to 70 feet deep. Since then the water has risen in many of these wells to within 4 or 5 feet of the surface.

Where seepage is not excessive it furnishes an inexpensive method of irrigation; where it is it may cause a double injury. It prevents the growth of crops because of too much water, and renders the soil unproductive through the accumulation of alkali which it causes.

Water passing from canals through the subsoil dissolves the soluble salts which all Western lands contain in greater or less measure, and the subsequent evaporation of this alkali-impregnated water so increases the percentage of alkali in the lower lands as to prevent the growth of crops. This evil is not, however, destined to be a permanent one, and, like the excessive moisture, can be remedied by drainage.

Q. (By Mr. FARQUHAR.) In Colorado and Wyoming is the general characteristic of your streams seepage or are they on solid ground and solid bottom?—A. In both of those two States, as a rule, the losses are not excessive in canals. There are exceptions, of course, but in both eastern Colorado and eastern Wyoming the soil is of a character to hold water pretty well, although in the older districts in Colorado there is a considerable area of land in the low bottoms along the streams that has become supersaturated both with water and alkali. This is not altogether due to losses from ditches. Probably the greater part comes from putting too much water on the fields. It is rather a drainage from the area irrigated.



FIG. 1.—APPEARANCE OF IRRIGATION CANAL WHEN FIRST COMPLETED.



FIG. 2.—APPEARANCE OF IRRIGATION CANAL TEN YEARS AFTER COMPLETION.



Q. The characteristic of the Arkansas from its source north of Leadville to its reaching the Mississippi has usually been characterized as a river of seepage. Anywhere along the banks, by digging a few feet down, you reach a well. Is it not a fact that that river itself, in its whole course, a good part of it, is really below the surface?—A. All of the rivers that flow out on the plains sink into the sand of their bed. I did not take your question as applying to the rivers, but rather to the ditches.

Q. The point was this, that many of the foothill streams east of the mountains—would not the seepage be generally supposed to amount to a great deal or do much harm; but when you come to a river like the Arkansas, with a large body of water passing over plains with very little fall, the water itself is drawn out and distributed a good deal in the banks and surrounding low ground?—A. That is true of all the streams flowing from the Rocky Mountains' out on the plains. It is a characteristic of the Rio Grande, of the Arkansas, the South Platte, and the North Platte. The North Platte has been measured 100 miles west of the Wyoming border and found to carry 400 cubic feet per second, while a few miles east of the Nebraska and Wyoming border it was entirely dry. The entire 400 cubic feet per second had sunk into the sand.

FILLING OF CANALS BY SILT.

Q. Have you anything to say about the filling up of these canals with silt and other substances that are quite expensive in canaling?—A. The canals taken out of the lower portion of those streams running out on the plains are more or less troubled by the moving sands in the bottom of the stream, that tend to fill them up; and all canals that are taken out of rivers that carry considerable quantities of mud in high waters have to be cleaned out every year. The deposits of mud can be handled as a rule without any excessive expense, but in streams like the North and South Platte and the lower part of the Arkansas the sand question is quite troublesome; and on the lower part of the Rio Grande the question of mud becomes an important factor. The red rise in the Rio Grande occurs when there are torrential rains along certain portions of the river where there is a red soil, and enormous volumes of mud are washed down in the river. Samples of the stream taken at that time have shown as high as 17 per cent of solid matter. All the ditches have to be closed during the time of the red rise because they would immediately fill up.

At Las Cruces, N. Mex., is one of the oldest ditches, if not the oldest ditch, in the United States. That ditch was formerly a channel cut below the surface of the ground. Now it is raised 4 or 5 feet above the surface of the ground. As the mud which was carried into the ditch was cleaned out each year it was thrown on the banks; and

when the banks became so high as to be troublesome they simply let the mud fill up a foot or so in the bottom. In time the ditch got above the stream, and they had to move the head farther upstream. In the period of operation of that canal the head has been moved upstream 3 or 4 miles from the original location. Not only that, but since the time the irrigation began the level of the soil on which the water and mud has been spread has been raised from a few inches to 2 feet—higher, of course, nearer the ditch, and becoming thinner and thinner as you recede from it. The Rio Grande at El Paso has filled up its channel from this cause until the river itself is higher than some of the streets of either El Paso or Juarez.

CONTROVERSIES OVER TITLES TO WATER.

ABSENCE OF PUBLIC PROTECTION OF WATER RIGHTS.

Q. (By Mr. A. L. HARRIS.) Has there been any conflict between irrigators on account of priority of rights?—A. In recent years litigation and controversy over the division of water has been alike a conspicuous and injurious feature of our irrigated agriculture. It has been due to two causes. The first is the lack of any plan for the establishment of rights to a stream, or public protection of those rights. When the men along the lower end of a stream see its waters shrink and their crops burning up for the lack of water they realize that it is due, not to the absence of the snow in the mountains, but to the fact that later ditches above them are robbing them of their just share. Before the farmers will permit the loss of their year's labor from this cause they will resort to almost any expedient to obtain what they believe belongs to them, and so they organize raids to tear out the dams above, or go into court to obtain legal redress. The remedy for this is to have water divided under public control. In the four States where this has been done irrigators are far more contented and controversies far less numerous and injurious than where no such control has been exercised.

EXCESSIVE APPROPRIATIONS OF WATER.

The second reason for controversies has grown out of the mistakes made in the adjudication of rights to streams. In the study of the water-right problems of California recently completed there were claims for 28,630,932 inches from a stream which can not be relied upon to furnish 10,000 inches. On another stream which carries in the irrigation season less than 200 cubic feet of water per second there were claims amounting in the aggregate to 147,600 cubic feet per second. On another river whose greatest measured flow is less than 60,000 cubic feet per second there are claims amounting in the aggre-

gate to 461,794 cubic feet per second, in addition to six separate claims to the entire supply.

The situation in California is the situation in nearly every other arid State or Territory. Before the value of water was appreciated titles to its use or control in amounts far beyond the present or any possible future need of appropriators were repeatedly established, and the question whether these excess rights are now to be corrected or to be recognized as vested rights is one of the grave issues confronting irrigators, lawmakers, and courts in every Western State.

In 1884 and 1885, while acting as assistant State engineer of Colorado, I measured the ditches of northern Colorado on the streams which had been previously adjudicated. My report of these measurements called attention to the discrepancy between the decreed appropriations and the actual carrying capacity of these ditches and canals in the following terms:

So great was this in some instances that the result of the gagings and the decreed capacity seemed to have no connection with each other. Ditches were met with having decreed capacities of two, three, and even five times the volume they were capable of carrying, ever have carried, or will probably ever need. Other ditches in the same district have decrees which fairly represent their actual needs. It needs no argument to show the worse than uselessness of these decrees as a guide to the water commissioner in the performance of his duties.

When these decrees were rendered the majority of appropriators believed that rights for irrigation were limited to the lands already irrigated, and that so long as used there the actual volume stated in the decree cut very little figure. Hence there was little solicitude on the part of late appropriators as to any danger arising out of excessive grants. Under the terms of these decrees each appropriator is entitled to a definite volume of water, described in cubic feet per second, and to a continuous flow of this volume throughout the year.

Recent decisions have recognized the right of the holders of these decreed appropriations to sell the entire volume granted. As a result, the owners of earlier priorities are enlarging their ditches and extending them to other lands, or, where this is not possible, are attempting to dispose of the surplus to other users. Every attempt to do this, however, is contested. The truth is that irrigators have, in practice, been building up a system of one theory of water rights, while the courts have rendered a number of decisions based on another theory. We have now reached a point where one of the two must give way. If the doctrine laid down in these decisions is carried to its logical conclusion, it will transfer the ownership of a majority of the streams of northern Colorado to a few early appropriators and compel a large proportion of the actual users of water to purchase from such appropriators the water they have heretofore had for nothing. That this is not an extreme statement is shown by the accompanying diagram

(fig. 1), which exhibits the relation between the mean monthly discharge and the decreed appropriations of the Poudre River.

The last examination of the records showed there were 104 appropriators from this river, the aggregate of these rights being 4,632 cubic feet per second, each right being for a continuous discharge of the volume decreed; yet in August of 1894 the stream carried only 162 cubic feet per second; in August, 1893, 141 cubic feet per second, and

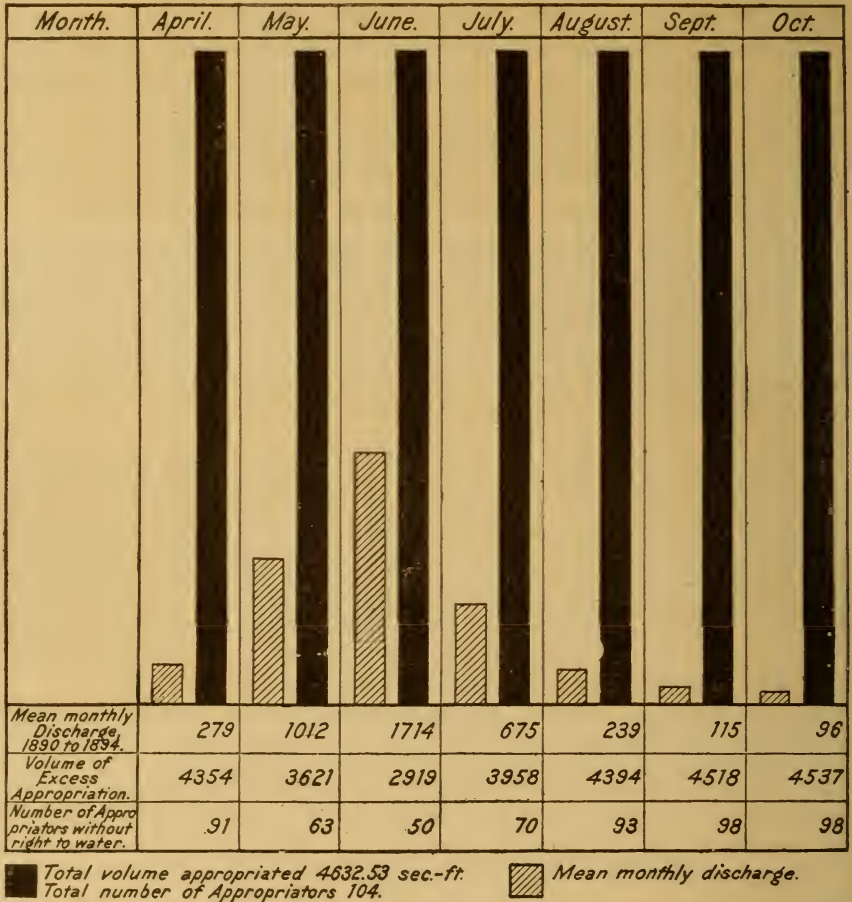


FIG. 1.—Relation between the mean monthly discharge of the Poudre River and the appropriations therefrom.

the stream has frequently fallen during the irrigation season to below 100 cubic feet per second. If the holders of these rights had lived up to their opportunities during the last half of their irrigation season, fully one-half of the actual users of water would have had to buy from the holders of these excess rights every gallon of water used after the middle of August. That they have not been compelled to do this is due to the fact that irrigation practice in that State is superior to irrigation law.



FIG. 1.—THE HEADGATES OF AN IDAHO CANAL.



FIG. 2.—SIDE HILL CONSTRUCTION ON AN IDAHO CANAL.



FIG. 3.—IRRIGATED FARM IN IDAHO.

The appreciation of the dangers which this situation creates is not confined to farmers alone. In a different brief from the one before referred to it is thus forcibly stated by Judge Elliott:

Excess priority decrees are a crying evil in this State. From every quarter the demand for their correction is strong and loud. Such crying demand can not be silenced by declaring that the meaning and effect of such decrees can never be inquired into, construed, or corrected after four years.

In many cases such decrees are so uncertain, so ambiguous, so inequitable, so unjust, and their continuance is such a hardship that litigated cases will be continually pressed upon the attention of the courts until such controversies are heard and settled, and settled right. Litigation in a free country can never end while wrongs are unrighted.¹

The settlement of this issue is not of local importance. It concerns the State and nation as much as the individual irrigator. The individual irrigator needs to know who owns the water he uses, if State or national aid is to be extended. It needs to be known who owns the water which public funds render available.

PRINCIPLES GOVERNING WATER RIGHTS IN CANADA AND WYOMING.

Before either public or private development proceeds much further there is need of some more general agreement regarding the nature of a water right than now prevails, as well as some more effective means of disposing of streams than has yet been provided. For several years Canada has been dealing with this problem, and has finally reached a definite result. The fact that their conditions are similar to ours makes the general principles which underlie the Canadian irrigation code worthy of our study. These principles are given below:²

(1) That the water in all streams, lakes, ponds, springs, or other sources is the property of the Crown.

(2) That this water may be obtained by companies or individuals for certain described uses upon compliance with the provisions of the law.

(3) That the uses for which water may be so acquired are "domestic," "irrigation," and "other" purposes, domestic purposes being limited to household and sanitary purposes, the watering of stock, and operations of railways and factories by steam, but not the sale or barter of water for such purposes.

(4) That the company or individual acquiring water for irrigation or other purposes shall be given a clear and indisputable title to such water.

(5) That holders of water rights shall have the protection and assistance of permanent Government officials in the exercise of such rights.

(6) That disputes or complaints regarding the diversion or use of water shall be referred to and settled by the officials of the Government department charged with the administration of the act, and that decisions so given shall be final and without appeal.

It is interesting to compare these principles of the Canadian law with those underlying the Wyoming irrigation code, Wyoming having

¹ U. S. Dept. Agr., Office of Experiment Stations Bul. 58, pp. 30-32.

² U. S. Dept. Agr., Office of Experiment Stations Bul. 96, p. 12.

gone farther than any of the other arid Commonwealths in the direction of public control of streams. These follow:

First. That water is not subject to private ownership, but is the property of the State.

Second. That the board of control is the trustee for the administering of a great public trust in the interests of the people of the State.

Third. That all rights to divert water from the streams must be based on beneficial use, and that the right terminates when the use ceases.

Fourth. That the volume diverted shall in all cases be limited to the least amount actually necessary for the accomplishment of the purposes of the diversion.

Fifth. That under no circumstances shall the water diverted for irrigation exceed 1 cubic foot per second for each 70 acres of land actually irrigated.

Sixth. That the right to the use of the public waters attaches only to the use for which the right was originally obtained.

Seventh. That the right of diversion for irrigation attaches to the land reclaimed and none other; that the transfer of the land carries with it the right, and that apart from the land the right can not be transferred.

Eighth. That when a ditch waters land not the property of the ditch owner the right attaches to the land on which the water is used and not to the ditch. The owner of the lands irrigated makes the proof of appropriation and the certificate is issued to him. No certificate of appropriation can be issued to a ditch owner for the watering of lands not his own. The ditch owner is a common carrier and is subject to regulation as such.

Ninth. That when proper diligence has been exercised in the construction of works and in applying the water to the purpose for which it is diverted the priority is fixed by the date of beginning the survey. When diligence is lacking, the priority dates from the time of use.¹

STORAGE OF WATER FOR IRRIGATION.

RESERVOIRS IN THE WEST PRIVATE PROPERTY.

Q. (By Mr. FARQUHAR.) Does the State control the reservoirs?—A. Except for two or three reservoirs in Colorado, all the reservoirs there are in the West are private property, and their owners exercise the same control over them that they do over ditches. Irrigation from reservoirs has not yet, however, assumed much importance as compared to irrigation from canals which take water directly from the streams. So long as there is water running in a river which can be diverted there is no need of reservoirs, since storage is only an added expense to the direct diversion from streams. On every river, therefore, reservoirs receive little attention until the natural flow has been utilized; that is, on rivers having a perennial flow. On the Poudre River in Colorado, however, the natural flow has been exhausted and an extensive system of private reservoirs has been built to supplement it.

Q. (By Mr. KENNEDY.) How far is Greeley from the head of the stream that feeds their canal?—A. About 125 miles from the head; about 40 miles below the head of the upper ditch.

¹ U. S. Dept. Agr., Office of Experiment Stations Bul. 96. pp. 49 and 50.

Q. Are there lands adjacent to that river all the way to the head, as well as the Greeley Colony lands?—A. Only to where the stream leaves the mountains, about 40 miles above.

Q. Plenty of water for all?—A. No; there is plenty of water early in the season, but they have had to resort to storage to secure enough for the later part of the season.

Q. (By Mr. A. L. HARRIS.) Is there a possibility for storage so as to economize the water at dry seasons?—A. Yes.

STORAGE MAKES PUBLIC CONTROL NECESSARY.

Q. What is the effect, if any, of storage on prior rights?—A. That is a troublesome question to answer.

We will take up the question of storage in connection with this matter. Bulletin 92 deals with the subject of storage on the Poudre River. It is the stream where storage has been carried further, probably, than any other in the whole Rocky Mountain drainage area. The diagram of the run-off of that river in the different months of the irrigation period for a large number of years shows that distribution of water during the season is far from uniform. The highest water occurs in May, and from the middle of May to the middle of June nearly half of the entire year's discharge runs away. The needs of irrigators in this valley are not in accord with this variation in discharge. They are now growing crops which require more water in July, August, and September than the stream will supply, and this has made it necessary for them to build reservoirs to hold back the surplus flow of the early summer months until it is needed. They have done this by utilizing natural depressions which lie outside of the channel of the stream, which are filled by the higher canals and turned into the lower ones. The development of this reservoir system has given rise to a very interesting system of exchanges between the canals, described in this bulletin, and hence need not be referred to here. Where reservoirs are located outside of the channel of streams there is no question of public policy involved in their construction and operation as private works, and as irrigation extends there will be more and more private capital invested in such reservoirs, because these investments are proving exceedingly profitable. But where reservoirs are located in the channel of running streams, and especially in the mountains on the headwaters of these streams, there is a question of public policy as to whether or not they should be built as public works, even if private capital is willing to undertake their construction. The water from reservoirs so located has to be turned into the natural channel of the stream and carried down with the natural flow to the valleys where it is to be used. If there is no public control of streams, irrigators will not discriminate between the natural flow and the stored supply. They will raise their headgates and take whatever comes in. Unless there is some means for the public regu-

lation of headgates, those having no right to the stored supply will oftentimes have a better opportunity for securing it than its legitimate owners. If public regulation is attempted, certain perplexing questions are sure to arise. If there are no restrictions on the price that the owner of the reservoir charges for his water, those injured by public control will be certain to urge that the taxpayer's money is being expended for the benefit of an oppressive monopoly. If the law which protects the reservoir owner also regulates the charge which he may make for water, there will still be controversies as to whether the rate is reasonable. If, however, these reservoirs at the heads of streams are built and operated as public works and the water they impound used to make more secure the supply of the appropriators of the natural flow, just as bridges are built to facilitate the safe and comfortable travel of people of different communities, all these troublesome questions will be avoided. There can be no question, however, that the construction of reservoirs on the heads of streams makes necessary one of two things, either public ownership of the supply or public protection in the delivery of water stored in private reservoirs. Last year I had an interesting experience in observing the emptying of a reservoir built as a private enterprise on one of the tributaries of the Weaver River in Utah. The owners of this reservoir irrigate their lands from a ditch which diverts the stream many miles below. Between the outlet of their reservoir and the headgate of their canal were eleven other ditches, all willing to share in the stored supply. There is no public control of streams in Utah, and the manager of the reservoir was greatly disturbed to know how he was to get the stored water past the headgates on the eleven ditches and down to the head of his own canal. In reply to his inquiry as to how I would accomplish it, I asked him how he had gone about it the year before. At first he was reluctant to tell, but finally said that he turned down enough water to wash out all the intervening dams, thus leaving a clear passageway. Before the dams could be repaired the reservoir had been emptied. He realized that this year the same expedient could not be employed. Fortunately, a temporary compromise was effected, which answered for the season, but the same issue must be met next year, and there will be no enduring peace or stability until the whole matter is regulated by law.

There is no question but that the subject of reservoirs will in the next few years assume a much greater importance than it has in the past, because on many streams it is the only means by which the area now irrigated can be extended. We can not determine too soon, therefore, whether we are to continue to permit their construction as private works or to build those on the head of streams as public works. I believe reservoirs located away from the channels of streams can be safely left to private enterprise. I believe those built to supplement



FIG. 1.—HEAD OF GAGE CANAL, CALIFORNIA.



FIG. 2.—DIVISION BULKHEAD OF GAGE CANAL, CALIFORNIA.

the natural flow of streams and to meet the needs of a number of ditches or canals should be public works. Whether they should be State or national works depends on whether or not the present policy of having all rights to water regulated by State laws is to be continued. If it is, these reservoirs should be State works and owned and operated as a part of the State system.

Q. Should that matter be determined at an early date?—A. It ought to be, in order that both State and national laws shall be in accord with the policy adopted. Any uncertainty regarding future legislation is also likely to interfere with the building of ditches and the reclamation of new land by individuals or corporations. The success of irrigation depends so largely on the wisdom or weakness of the water laws in force that if any changes are to be made the sooner they are made the better.

IRRIGATION A STATE QUESTION.

Q. Is there any reason why the State could not take hold of the whole subject of irrigation within the State and thereby protect the private landowners?—A. There is not. On the contrary, the fact that the subject is of paramount importance in each one of the arid States, that the people who have made the beginning understand local conditions and necessities, makes it possible for the States to bring to the solution of the problems of irrigation a higher intelligence and more direct interest than can be secured in any other way. That they have not succeeded in the past has been due in part to a lack of appreciation of the necessity for legislation and to a disagreement regarding the principles which should govern the ownership of water. The States are entirely capable, in my judgment, of regulating and protecting all interests connected with this subject; but they are not capable, under present conditions, of securing the full utilization of their resources. As I have before stated, on some of the larger rivers it will cost more to irrigate land than private capital can afford to expend. The building of reservoirs as public works to provide for the larger utilization of rivers does not appeal to private investors. In both cases, however, there is an argument in favor of the expenditure of public funds which does not appeal to the private investor. The public reaps benefits from the construction of irrigation works which private capital can not share. It gives to land now worthless a high value, and largely increases the taxable resources of the States and the productive wealth of the whole country. If the arid States were in a position to build canals and reservoirs, there are many instances where it would be wise public policy for them to do so; but, unfortunately, they lack the resources to undertake this. They are young and sparsely populated, the expenses of maintaining local government are heavy, and all of this has to be paid for by taxes levied on only a small fraction of the land within the borders of each

of these States. The table which follows shows how large a percentage of the area of each of these States is still public land. It contributes nothing in the way of taxes to the local government and can not be used as a basis of credit to borrow money for its improvement.

Total area of each of the arid and semiarid States, the area of public land remaining undisposed of, and the area set apart for Indian reservations.

State or Territory.	Total area.	Undisposed of and unreserved.	Indian reservations (estimated).
	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>
Arizona	72,876,800	50,286,988	15,150,757
California	101,209,120	42,467,512	406,396
Colorado	66,540,160	39,659,247	None
Idaho	53,649,920	43,286,694	953,635
Kansas	52,631,040	1,196,900	28,279
Montana	94,119,040	67,963,657	9,590,700
Nebraska	49,619,840	9,798,688	74,582
Nevada	70,834,560	61,277,506	954,135
New Mexico	78,519,680	56,541,170	1,667,485
North Dakota	45,962,560	18,725,239	3,701,724
Oregon	61,976,320	34,377,907	1,300,225
South Dakota	49,651,200	11,930,809	8,991,791
Utah	54,353,920	42,967,451	2,039,040
Washington	45,167,360	11,125,883	2,333,574
Wyoming	62,641,920	48,358,169	1,810,000
Total	959,213,440	528,958,630	48,912,353

It has been suggested, and a number of bills have been introduced in Congress embodying the idea, that the States be given the proceeds of the sales of public lands within their borders as a fund with which to construct important public irrigation works. The following table shows how much the States would have realized from this during the year 1900:

Receipts from the sale of public land in the arid States and Territories for 1900, less cost of local land offices.

State or Territory.	Amount.	State or Territory.	Amount.
Arizona	\$32,000	North Dakota	\$314,000
California	120,000	Oregon	284,000
Colorado	172,000	South Dakota	159,000
Idaho	126,000	Utah	67,000
Montana	377,000	Washington	182,000
Nebraska	72,000	Wyoming	166,000
Nevada	7,000		
New Mexico	38,000	Total	2,107,000

LEASING OF THE PUBLIC GRAZING LANDS.

These revenues represent sales of land. They can be largely increased if some system is devised for collecting a revenue, by rentals or otherwise, from the public grazing lands. It must be borne in mind that only a small fraction, probably not more than 10 per cent, of all the lands of the arid region can be irrigated, while of the arid land still remaining public the irrigable percentage is much smaller, certainly not over 5 per cent and probably not over 2 per cent. The reason for this is that lands easily irrigated have passed into private

hands. The public lands along many rivers require more water than the streams contain. Of the remainder of the public lands more than 400,000,000 acres are grazing lands, valuable for pasturage purposes alone. Sooner or later it will be necessary for the Government to exercise some sort of management or control over these lands in order to prevent neighborhood controversies and preserve the native grasses from being destroyed from overstocking the range. If in connection with this a leasing system could be devised which would unite the grazing and irrigable lands in such a way that each irrigator could have a right to lease a small area of the contiguous pasture land, a large income from rentals would be secured and both the irrigable and grazing interests put on a more secure footing than now. In order to show the possibilities of these rentals the following table has been prepared to show the income some of the arid States receive from the small areas they lease:

Summary showing results of leasing State and Territorial lands in some of the arid States and Territories.

State or Territory.	Total area of State or Territorial lands undisposed of.	Acreage under lease at close of last fiscal year or biennium.	Total rents received.	Average rental per acre.
	<i>Acres.</i>	<i>Acres.</i>		
Colorado	3,689,968	1,251,770	\$103,121	\$0.082
Idaho		32,271.98	23,050	.614
Montana		965,912	112,467	.112
Nebraska	2,483,372	1,879,143	(a)	
Utah		106,531	6,300	.059
Wyoming		1,969,945	80,841	.041

^a Total receipts for biennium ending November 30, 1900, for interest, rentals, bonus, etc., were \$782,975.65.

NATIONAL AID EXTENDED BY LAND GRANTS.

A few of the States have received aid in the way of land grants. Colorado was given 500,000 acres of land to provide a fund for making public improvements. Some of this money has been spent on irrigation works.

Q. What is the name of that grant?—A. Public-improvement fund. Reservoirs and ditches are not the only public improvements for which this fund could be expended. Roads and bridges belong to the list, and the greater part of the fund has been expended in their construction. Utah was given 500,000 acres of land to provide a reservoir fund, but that was a recent donation, and I do not think that any of the lands have been sold. There are other means, however, for promoting the growth of irrigation besides the appropriation of money. The present land laws were framed for the humid region. They do not meet the requirements of the arid region. The benefits which can come from their modification have been illustrated in the passage of what is popularly known as the Carey Act, which gave to each State

the power to control 1,000,000 acres of land during its reclamation. It has resulted in the irrigation in Wyoming of about 100,000 acres of land which would never have been reclaimed under the public-land act. The projects inaugurated under the Carey Act in Idaho embrace in the aggregate about 400,000 acres. In both of these States the conditions of irrigators are rendered superior to the average result where land is reclaimed under the homestead or desert-land acts. To acquire land under this act in either of these States there must be actual settlement and cultivation. No one can acquire more than 160 acres, but attached to that 160 acres is a water right and a share in the canal which supplies the water under it.

COST AND VALUE OF IRRIGATION.

Q. I believe you have not said anything yet in regard to the cost of irrigation and its value, have you? I do not want to anticipate.—

A. No. The first ditches built always are the cheapest. Men go along streams and find a place where they can take out little ditches in the favorable bends, and such ditches cost but little more than later laterals from main canals.

Q. (By Mr. LITCHMAN.) Have you gone over the manner of making the ditch?—A. Yes. So that from a great many of the earlier ditches water was taken out and spread over the lands for anywhere from \$2 to \$5 an acre. A great deal of land was irrigated and ditches were built for prices not to exceed that. When you come to building large ditches you have the expense for the lateral and also the expense for the main canal, and there the expense runs all the way from \$5 to \$15 an acre. We have about reached the point where the cost is above that, because we are now dealing with the large rivers that require costly headgates and where the fall is less than where the first small ditches were built. While the streams that were first used had a fall to the mile ranging from 5 to 50 feet, we now have to deal with such streams as the Missouri, which has a fall of from 2 to 10 feet to the mile, and the Big Horn, with a fall during a large part of its course of about 4 feet to the mile. There you have to build a much larger canal to get onto the table-land bordering the river, or you have to build a costly dam in the river to raise the water up at the outset, and the larger projects which remain to be built will require a much larger outlay. The estimates on a good many of these canals range anywhere from \$7 to \$20 an acre for water, and that is a higher price than can be paid, because there has to be added to the cost of the water the cost of the settler's equipment, including the expense of his house, his tools, his stock, and of putting his land into condition for cultivation. The surface of the land has to be smoothed off so that the water can be made to flow over it, and in many cases where there is sagebrush on the land it has to be removed; so that the expense of putting the land in condition for distribution of water is frequently



FIG. 1.—VIEW OF A STOCK RANCH AT MESA, ARIZ.



FIG. 2.—AN ALMOND ORCHARD IN ARIZONA.

almost as much as the land is worth. And in many places where there is an abundance of land it is not being developed, because it would cost as much to develop it as it would to buy an improved farm in the older States in the Mississippi Valley. There is no inducement for immigration under such conditions.

Now, the value of irrigated land is governed by nearness to local markets, by the climate, which governs the kinds of products grown, and by the distance and cost of railway transportation to the great markets of the world. In southern California and around Phoenix, Ariz., where you can raise citrus fruits and other high-priced products, irrigated land reaches a value as great as is found anywhere in this country, or perhaps in the world. There lands having no improvements except the orange orchards planted on them have sold as high as \$1,800 an acre, perhaps higher. I have seen lands that sold for that price in southern California, and water has a corresponding value. Water rentals reach to figures that would be impossible elsewhere in the irrigated sections. I know of instances where water rents for \$45 an inch a year, and where rights to it reach as high as \$1,000 an inch. Now, when you come to the northern part of the arid region, the portion that competes with the agricultural districts east of the Rocky Mountains, there you get into districts having cheaper water supplies and cheaper lands.

PRODUCTS OF THE ARID REGION.

Throughout its greater part the arid region will always be largely devoted to the raising of live stock and to gardens to supply the mines and the manufacturing and commercial centers of the region. After you have satisfied your local market the only demand for your produce is for furnishing the winter's food supply for live stock, and aside from these two outlets there is no basis for any large development. The live-stock industry is largely based on the use as a grazing ground of the remaining public lands, and the private lands that have passed out of the hands of the Government or the railroads. Formerly it was the practice to turn cattle and sheep loose on these grazing lands and let them go from youth to old age without ever having any care or shelter during either winter or summer. They earn their subsistence off the open range. But that is now giving way to the practice of feeding in winter. This is not voluntary; it has been forced. The overpasturing of the public and private grazing lands has made it impossible to depend on them for the winter's food supply, and you have to provide for it from other sources. Therefore, you have to depend on the irrigated lands. Those lands, to be available, have to be distributed throughout the range country, because when the storms come in the winter you can not supply stock 50 or 100 miles from a railroad, even if you had an unlimited supply of feed at the railroad. It is impossible to transport it. You must

store it where it is needed, and the needs of the live-stock business have been one of the great incentives to irrigation, and furnish one of the best markets for grown crops, principally native hay and alfalfa. Those are the two leading general products of the grazing region.

Q. (By Mr. A. L. HARRIS.) Would it be possible to raise wheat and corn at a profit with the high price for water rights?—A. I do not think corn can ever become a general crop under irrigation. It is grown in restricted areas as a part of the system of rotation, but there is a considerable portion of the arid land where the nights are too cold for it. In fact, it is a characteristic of the arid region that the nights are too cold to make it a corn-growing region. Besides, alfalfa is a better stock food, and you could not grow corn at a profit if you had to ship it out. The same thing is true of wheat. Unless there shall be a market which can be reached by water, and without excessive railroad charges, there will never be any large development of the wheat-growing industry in the irrigated regions. You can not grow it and ship it out. The great bulk of the wheat grown now is consumed at home, and in a good many of the arid States enough is not raised to supply the home demand—not nearly enough. Montana, Wyoming, and Idaho are all importers of flour. They are also considerable importers of oats. They have not reached the point where they supply the home demand, and it is true of nearly all those States that the development of mining the precious and useful metals and the resulting growth of the home demand for the local food supply is now going on faster than the extension of irrigation. Furthermore, when we have done all we can there will not be 10 per cent of the territory west of the one hundredth meridian and east of the rainy districts on the Pacific coast that can ever be brought under cultivation. Either there is not the water or it is not available. We can never make use of but a small fraction of the Columbia, it is certain we can never utilize all of the Colorado, and it is doubtful if we can ever completely use the Missouri.

Q. (By Mr. LITCHMAN.) Have you gone into the question of artesian wells?—A. Yes; I know something about artesian wells.

Q. Would it be true if the land were irrigated, as you propose, that a given quantity of stock could be raised on a less area of land?—A. Oh, yes; I think so.

Q. And would not the limited amount of land as suggested by you be compensated by that fact?—A. Oh, yes; only you would have a great many more people. As it is now a great many men interested in the stock business will occupy 50,000 or 100,000 acres of land with flocks and herds. This plan I have suggested would make smaller flocks and herds and larger farms.

Q. (By Mr. A. L. HARRIS.) Would the lease system be better than the absolute title?—A. The only objection to the disposal of the public



ARTESIAN WELLS, HEAD OF GAGE CANAL, CALIFORNIA.

land by absolute title would be that there may be some of the land so disposed of for grazing purposes which is irrigable. I should say that the better plan for the present as a tentative measure would be the lease system; perhaps not ultimately, but simply as an alternative or a temporary measure.

Q. How long would you have the lease?—A. Not for more than five years, and I would have every tract of land leased remain subject to entry under the public-land laws and have the man who leased it take it with that condition. I would not restrict the operation of acquiring title under the present land laws at all, but would leave those open even on leased lands. It is my judgment that men would lease land and take those conditions; that is, men who leased land would know whether or not a homestead or a desert-land filing can be made on it, and if they select land that is irrigable and subject to cultivation they take their chances.

Q. (By Mr. FARQUHAR.) These remarks that you make are predicated on the fact that you do not interfere with land already disposed of under the public-land laws?—A. Entirely.

Q. You can not dispose of them or subdivide them?—A. No. You see there are between 300,000,000 and 400,000,000 acres of public grazing lands. My plan relates entirely to that land.

Q. (By Mr. A. L. HARRIS.) The earlier, then, some steps are taken in the direction of a general plan the better?—A. I think so.

Q. There has been a survey of a portion of this arid country by the Federal Government, has there not?—A. Nearly all the country is now subdivided by the general surveys. I think that a leasing system could be inaugurated, so far as that is concerned, without any additional survey. If you leave the lands subject to entry just as they are now there is no need of discriminating as to whether the lands are agricultural or pasture; they are open to entry just the same after they are leased as before they are leased. If you are going to make the lease absolute, so that when a man leased land for five years you could not file on it, then you would want to have an economic survey, and know absolutely what were irrigable and what were pasture lands; but if you do not make it absolute, and you make it simply conditional and leave it to the man who leases, then if he does not want to be interfered with, to go outside of the irrigable territory himself, then it would not make any difference.

NATIONAL AID FOR IRRIGATION.

Q. What has been the objection heretofore to the Federal Government adopting some plan of irrigation?—A. I do not think there has been any objection, except that in the East there has been a feeling that any large development of agricultural lands there would interfere with the prosperity of farmers in the East; that has been one objection outside of the irrigated territory. And there has been a

question as to whether or not this was a matter which the General Government could take in hand without transcending the limits of the Constitution. That relates more, however, to appropriations of money for work. There can be considerable legislation without an appropriation of money that will very materially promote successful development and which can properly precede appropriations of money or the determination of how money is to be appropriated. In the West there has been, and will be until this matter is settled, considerable discussion about the best means of extending Government aid, growing out of the sensitiveness of people who have rights to any disturbance of those rights. Communities have built up their systems under local laws and customs and have become wedded to them and they do not want them interfered with. On the other hand, there is in the West another element in favor of turning this whole matter over to the National Government and having the National Government have a complete system of laws and administration; but to do that will necessitate a revolution of existing systems.

Q. (By Mr. FARQUHAR.) It seems to be a question, does it not, of artificial development through irrigation under the expenditure of the National Government and the natural development of the settlement of the country through the present land laws of the country?—

A. No, not that.

Q. Well, how is it?—A. It is a question between stimulated development under national aid or natural development, not under present land laws, but under laws framed to meet the conditions of the Western region.

Q. Whether under State control or national control as far as the land is concerned?—A. Yes.

Now, there is going to come a time, and that time is here now, when there will have to be an expenditure of public funds in order to secure certain kinds of development. There are rivers, like the Missouri, from which I do not believe it will ever pay within our lifetime to take the water, because it will cost so much that the land will not pay for it. Irrigated land and the value of irrigation improvements is measured by the value of lands in the Mississippi Valley or the value of irrigated lands under cheaper works, and you can go only just so far with private enterprise. Now, there are projects that would pay as public works, perhaps, because in bringing land that is now worthless into a condition of productivity you create homes; you create taxable values that the public gets the benefit from, but that the private investor does not share in, and there is the argument in favor of State or national aid to certain classes of important works.

(Recess taken until the following day.)

Q. (By Mr. A. L. HARRIS.) Let me ask this question: If a stream is interstate is there danger of conflict of authority between the States as to the rights of water?—A. Yes; such conflicts have already

arisen and they are likely to arise in the future, although the importance of this question is not nearly so great as securing a proper division of water between users inside of a State. The lack of any law to determine how the waters of an interstate stream shall be divided is only one instance of a number of the uncertainties which now exist regarding the limits of State and Federal jurisdiction over the control of rivers. There are in addition the conflicting rights of irrigation and navigation, which in California apply to rivers wholly within the State's borders. Here the Government looks after the rights of navigation and the State after the interests of the irrigator. The relative rights of navigation and irrigation have been raised in litigation over the waters of the Rio Grande, and the decision of the United States Supreme Court indicated so strong a tendency toward maintaining the interests of navigation as to give rise to considerable apprehension in many parts of the West. The conditions along the Missouri serve to show why this is true. This river drains a large part of the country east of the Rocky Mountains, and, with its tributaries, is the main dependence of Montana, the Dakotas, Wyoming, Colorado, Nebraska, and Kansas for the water used in irrigation. If it should become necessary to close the headgates to prevent steamboats from running aground it would put an end to all hope of any considerable increase in the acreage now cultivated. I believe, however, that this is a theoretical rather than a practical question, since, owing to the fact that the tendency of irrigation is to equalize the discharge of streams, reducing the floods and raising the low-water discharge, its extension on the headwaters of the Missouri will be a help to steamboats instead of an injury. It has been found that ditches along the lower end of a stream which formerly were unable to secure any water in July now have an ample supply the season through, because of the increased flow from seepage and percolating waters.

INTERSTATE WATER-RIGHT COMPLICATIONS.

Q. (By Mr. A. L. HARRIS.) Last evening when we took a recess you were about to take up the consideration of the Bear River country.—A. If the members of the commission will take Bulletin No. 70 and the map at the front (see Pl. XI), it will serve to illustrate the nature of some of the interstate complications. Bear River rises in Utah; the stream flows across the northern boundary of Utah into Wyoming. There is a section of it about 50 miles long in Wyoming, and then it crosses back on the western border of that State into Utah again. There is a section of 25 or 30 miles in Utah, and it crosses back into Wyoming, and then it leaves Wyoming and enters Idaho, and finally returns to the State of its source, Utah. This winding cuts that stream into five different sections, and there are ditches taken out of the stream along its entire course, and yet each

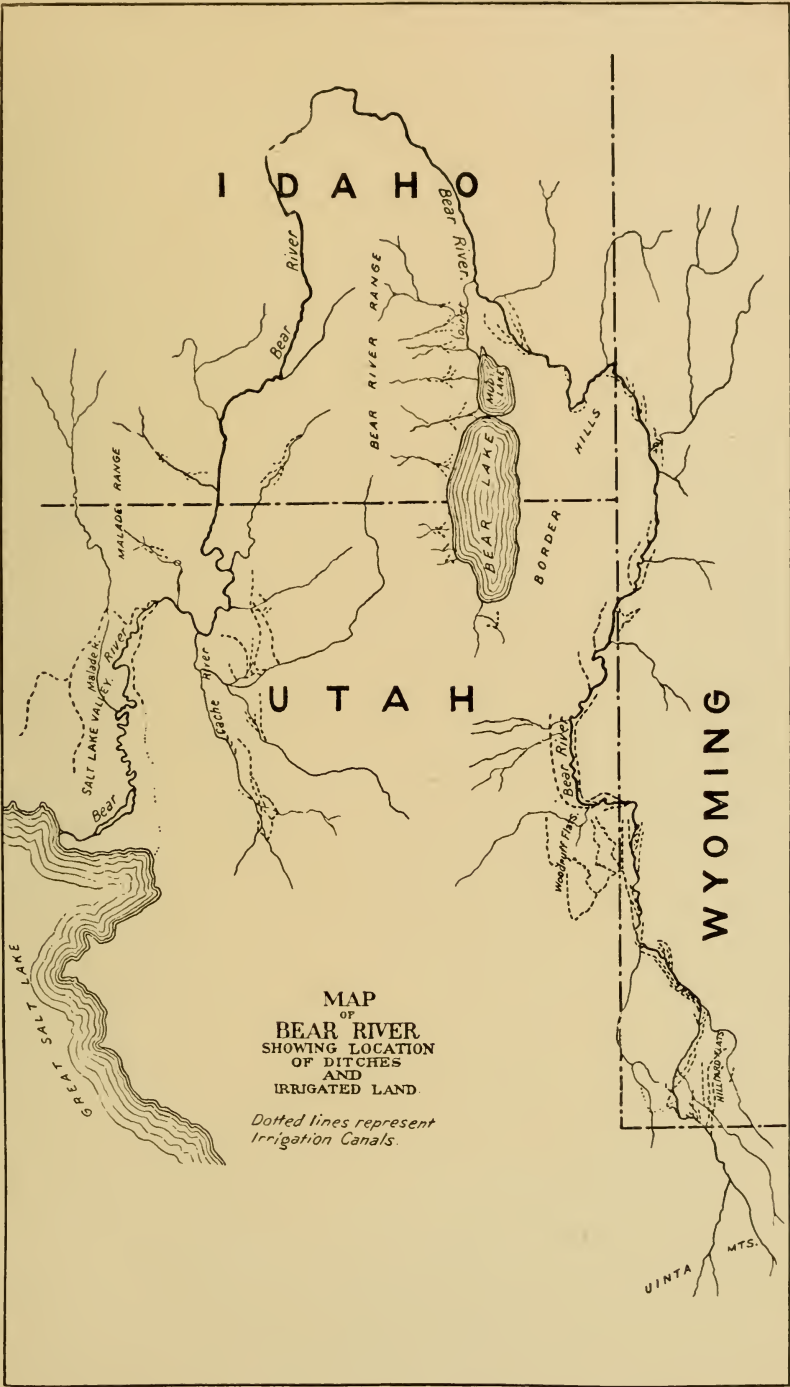
one of those sections is absolutely independent of the other. Take the two sections in the State of Wyoming. The people have complied with all the requirements of the State law. They have recorded their rights; they have permits to appropriate water, and the doctrine of priority is the theory of the State; but it is impossible to enforce that doctrine of priority, because some of the last ditches to be built have their headgates just over the border in Utah and the Wyoming authorities can not go over there to close down the headgates. Consequently those people, although they have the last ditches, have practically the first right to the stream. In the same way there is no use to attempt to enforce priorities on the upper section of the stream in Wyoming in favor of earlier rights on the lower section in Wyoming, because if the water were not taken out above it would simply go into Utah, and there appropriators would take it without any reference to Wyoming rights. Exactly the same thing is true in reference to the improvement of Bear Lake. There is an important storage basin that the irrigators on the lower end of the river desired to develop; but they were confronted by the fact that if they did store the water and turn it out into the stream all the ditches in Idaho would have the first chance to utilize that water supply, and they would have no means, unless it was recourse to the courts, to prevent it. Now, if we had been aware of the development that was coming, we could have avoided all those complications by changing the boundary about 10 miles. So far as Wyoming and Utah were concerned, it would have thrown the whole of that stream into Utah. There are a great many instances of this kind where a very slight change of State boundaries, having them follow divides, would have entirely obviated interstate questions; but as it is now it is one of those open, unsolved problems that will in time either be settled in the courts or by State or national legislation.

Q. You desired to make some reference to the California map. Have you that at hand?—A. That was simply to illustrate. We have the map here, but I think we have gone over the points. I may, perhaps, in speaking of the extent of irrigation and the restricted areas that are irrigated and will be irrigated, call attention to one of the California maps here that shows the relative area irrigated in the leading irrigation State of the country, with the unirrigated and uncultivated portions. The purple areas there are the areas that are irrigated.

Q. (By Mr. LITCHMAN.) Appears to be a very small portion?—A. Very. That is true of every State if you compare the total.

IRRIGATION IN THE HUMID SECTIONS.

Q. (By Mr. A. L. HARRIS.) Now, you will please take up the humid parts of the United States.—A. We have in this country been considering irrigation as a sectional matter, and it never will have the



MAP OF BEAR RIVER, SHOWING LOCATION OF DITCHES AND IRRIGATED LAND.

importance in the East that it has in the West. But there is every reason to believe that irrigation is to be largely employed throughout the humid portion of the United States in the growing of high-priced and special products. The work done in Connecticut, Massachusetts, and New Jersey shows that in the growing of small fruits irrigation is exceedingly profitable, and in market gardening it is now being largely utilized. The cranberry growers of Wisconsin and the farmers in the sandy pine lands of the Northwest are beginning to utilize irrigation as a means of getting crops started, of getting a sod established on those sandy lands; and there seems reason to believe that there will be quite extensive stretches of territory scattered through the humid districts where irrigation will be very largely employed. The market gardeners around our large cities in the East and the tobacco growers of Connecticut are using irrigation to some extent in the growing of fancy varieties; and in the South irrigation seems certain to have a very large usefulness. In the past five years more land has been brought under irrigation in southern Louisiana and southern Texas than in any single State of the arid region within that period, and there has been more money invested. Not only that, but in its engineering features irrigation in these States is entirely distinct from that of the irrigation of the arid regions. Now, in the arid regions water is conducted by gravity. You have a rapid fall away from the mountains which carries the water through the canals and away from the streams. But in the South the streams have little or no fall. They are simply reservoirs with the water in them practically stationary. You have to pump water up into canals, and then it flows very slowly, because the country has so little fall. So canals are built there that are simply banked reservoirs. Instead of a channel cut below the surface of the ground, two banks are built, sometimes 200 feet apart. Now, the canal is the land between those two banks. The banks could just as well be 400 feet apart.

The width of the canal has nothing whatever to do with the cost. These long lines of embankment will be built and the water pumped up from the river into the canal. Now, turning water out at different points causes the current; it is the inclination of the water surface rather than the inclination of the land. Now, in order to reach a higher territory, they establish at convenient points other pumping stations and raise the water up to a higher level. This method of irrigation has been extended until now the country embraced is about 200 miles in length and about 50 miles wide. It is not all irrigated now, but that is the total area in which irrigation is being extended.

The first canals were taken out of the sluggish streams that flow into the Gulf of Mexico; but when the importance or the value of the rice product became established and lands rose in value from \$5 to \$50 and \$100 an acre, it became manifest that those streams would not supply the need of water, and the farmers began looking about

for other sources of supply. They found one by putting down wells, so that the pumping stations to supply water from the rivers are being supplemented largely now by wells. Hundreds of wells are going down throughout that portion of Louisiana where rice is grown, and this year a study is being made to determine the source of that water supply. If the subsoil is simply filled with water and it can be pumped out, it will soon be exhausted; but there is a belief that it is being reenforced from the Mississippi. That was a conjecture at the time I was there, but a study is being made to ascertain if it is true. If it be true, there will be a capacity for indefinite extension of the supply by wells.

The success of rice growing there, after the long period in which we had been continually shrinking in our rice production, has led to increased interest in rice growing along the Atlantic seaboard. For years the rice growing there, if not unprofitable, has not been sufficiently profitable to lead to any extension. In fact there has been a constant decline. Old canals in use long before the war were going out of operation; but the industry is now being extended, and the question now is whether the Louisiana method can be adopted.

Rice cultivation in the Carolinas is largely after the methods prevailing before the war. The crop is harvested by hand—cut with the sickle and bound by hand. The reason it is so much more successful in Louisiana is the application of modern machinery. The crops there are cut with a self-binder. There have been economies brought into the field labor, and the methods of applying and distributing water are patterned after those of the West rather than those of the Carolinas. There is an economy in the distribution of water, and there is another very marked economy in the harvesting of the crop. An industry that was not before remunerative has been made exceedingly profitable.

The southern territory is also likely to develop irrigation in the growing of forage crops. Alfalfa grows in the South. It will not grow in the middle East; it freezes out in the winter and does not seem to thrive, but it will grow and live through the winter and become a perennial in Louisiana. There seems to be quite a field for the use of irrigation in the growth of alfalfa and other forage crops in the South wherever you can get water at a sufficiently low cost.

Now, the same questions arise in the East, where development has gone far enough, that have arisen in the West. In the South the question has come up between the different canals as to who has the better right to the water supply if more water is needed than the wells will supply. In time some system of priorities will have to be established there. They will have to determine how they are going to operate under the doctrine of riparian rights. That is an unsettled question there as yet, just as it is in the West. On one of the streams last year so much water was pumped out that the river changed its



FIG. 1.—WASTEWAY AND GAGEBY ARROYO, GREAT PLAINS WATER COMPANY.



FIG. 2.—OUTLET CONDUIT NO. 2, GREAT PLAINS WATER COMPANY.

direction and ran upstream for a distance of 50 miles. The current changed and ran back, and salt water came in from the Gulf and ruined the usefulness of the pumps in the stations farthest downstream. Those are matters that will require adjustment. If there should be in the East any considerable demand on the streams, the right to take water from Eastern streams will be called in question; so that the economic and legal phases of irrigation have already ceased to be sectional.

Now, there is a very large district, reaching from the Gulf of Mexico to the Canadian border, embracing western Texas, western Kansas, western Nebraska, and the western Dakotas, which were first settled up in their humid parts. They were settled up quite sufficiently in the western arid or semiarid parts to render irrigation problems important. They are in some respects among the best parts of the arid region, because ditches there can be built at small cost. It is a country well adapted to the distribution of water, and only a comparatively small amount of water is required to supplement the rainfall. As you go farther west, if you have only 10 inches of rainfall and increased evaporation, you must supply more moisture by irrigation than where you have 20 inches of rainfall and less evaporation; so a given amount of water will irrigate more acres there than farther west.

In this central region we have two questions. In the Dakotas it is very expensive to bring water from the Missouri River, and in Nebraska we have the uncertainty at the present time regarding the State law. Nebraska is comparatively well supplied with water. The North Platte is a stream that can not be utilized to any great extent in the west. The Loupe is a good stream; and they have in these two rivers an opportunity for a very large development. As you go south of that the difficulty in Kansas is the question as to the extent of the underflow and whether it is practicable to get some means of pumping it up.

When you go south into Texas you have still a different question. In southern Texas there is a considerable territory that can be irrigated from springs and wells, and also all the way through Arizona and New Mexico.

FILLING OF RESERVOIRS BY SILT.

A great many streams are torrential in character, carrying an immense flow of water and then running down to nothing. You must store these streams in order to make much use of their waters, and the problem of storage is a complicated one. It involves the question of the sediment in these Southern streams—the silt. It is disastrous to build a reservoir in the channel of a river, and, when you have a large investment in houses and people settled there, to have it fill up and necessitate these settlers moving out. It is simply

a waste of energy and a waste of money. That is a question that the Department of Agriculture is studying, and arrangements have been made with the agricultural college of Texas to gather samples from these streams and see what would be the probable result of letting the mud they carry deposit on the soil.

Q. Does evaporation go on so rapidly in some portions of the country that it would leave the reservoir salty?—A. The total evaporation from the water surface in the West ranges from 3 to 6 inches per month. Where the waters of the river itself are heavily charged with alkaline salts this evaporation will so concentrate them as to make it injurious; but there are very few instances of that kind. The only one that I know of personally is the Pecos River, and I think that action only occurred in one season. I do not think that would be a very important question. The streams carry so little alkali in the portion of the country where the water is stored that the accumulation would not amount to much. Then the water is discharged every year and there is no cumulative action. It is only the concentration that would take place in a single season.

(Testimony closed.)

APPENDIX.

EXHIBIT A.

Water right.

FRESNO CANAL AND IRRIGATION COMPANY.

[Incorporated February 16, 1871.]

FRESNO, FRESNO COUNTY, CAL.

This agreement, made the — day of —, 19—, between the Fresno Canal and Irrigation Company, the party of the first part, and —, the part— of the second part, witnesseth:

That for and in consideration of the sum of — dollars, gold coin of the United States, paid to the party of the first part by the part— of the second part, the receipt whereof is hereby acknowledged, and of the covenants and agreements herein contained, the party of the first part agrees to furnish to the part— of the second part, from the main canal of the party of the first part, or from a branch thereof, all the water that may be required, not exceeding at any time — cubic — per second, for the purpose of irrigating the —, in Township No. — south, range No. — east of Mount Diablo meridian, from the — day of —, 19—, until the 16th day of February, 1921, and during the existence of said corporation.

The party of the first part agrees to place a suitable box or gate in the bank of said main canal, or a branch thereof, at the most convenient point for the conveyance of the water to said land, as soon as the ditch to be constructed by the part— of the second part shall be commenced.

The part— of the second part will construct a ditch from said box or gate to said land at — own risk, cost, and expense; and it is covenanted and agreed that the ditch so constructed may be a branch ditch of said company, and be under the control thereof, at its option, and that said company shall have the right to use and enlarge said ditch, provided such use will not interfere with the flow of water to said land; and the part— of the second part hereby grant — to the party of the first part the right of way to convey water through any of — lands situated in said township to contiguous land.

The part— of the second part covenant— and agree— that — will not use or permit the water to be used on any other land except the land above described, or permit the water to run off on any contiguous land, or permit the water to spread out in low places on such land, or in any way to run to waste, and — will construct ditches to convey the surplus water, if any there be, back into the canal of said company, or a branch thereof.

It is understood and agreed that the water to be furnished under this agreement is intended to form a part of the appurtenances to said land, and the right thereto shall be transferable only with and run with said land, and that the party of the first part is bound by this instrument to all subsequent owners of said land, but to no other person.

The part— of the second part, for ———, ——— heirs, and assigns, covenant— and agree— that ——— and ——— successors in interest and estate in said land will pay annually to the party of the first part, at its office, in gold coin of the United States, on the first Monday in September, in each year, until the year 1920, and during the existence of said corporation, the sum of ——— dollars (\$———), and this instrument shall be deemed equivalent to a notice and demand on the day the same becomes due, by the terms hereof, and in case of default of such payment in any one year for the space of 30 days after it shall become due, this agreement shall terminate, and become thenceforth null and void and of no effect, at the option of the party of the first part, its successors, or assigns. And said part— of the second part covenant—, for ———, ——— heirs, and assigns, that ——— will pay all legal expenses, including a reasonable attorney's fee, necessarily incurred by said party of the first part in the collection of said annual payment.

And it is further covenanted that the party of the first part may shut off the water any fall, for purposes of general or special repairs of its canals, bulkheads, or gates, and at such other times as urgent necessity may require; but shall restore the water in said canals as speedily as the nature of the case will permit.

It is covenanted and agreed by the parties hereto that the party of the first part shall not be responsible for deficiency of water caused by drought, insufficient water in the river, hostile diversion or obstruction, forcible entry, temporary damage by flood, or other accident; but that the party of the first part shall use and employ all due diligence at all times, in restoring and protecting the flow of water in its canals and ditches.

It is understood and agreed that the party of the first part may sell 1,000 water rights of 1 cubic foot each, and if at any time the aggregate quantity of water in the canals of said company shall fall short of 1,000 cubic feet flowing per second then each water right shall represent the one-thousandth part of said aggregate quantity, and the part— of the second part shall be entitled to receive water in that proportion.

It is covenanted that this agreement and the covenants therein contained on the part— of the second part run with and bind the land.

It is covenanted that any violation of this agreement by the part— of the second part or ——— assigns shall render this agreement null and void and of no effect, at the option of the party of the first part, its successors or assigns.

In witness whereof the parties hereto have hereunto interchangeably set their hands and seals, the day and year first in this agreement written.

Executed in duplicate.

[SEAL.]

THE FRESNO CANAL AND IRRIGATION CO.,
By ———, *President*.

[SEAL.]

THE FRESNO CANAL AND IRRIGATION CO.,
By ———, *Secretary*.

EXHIBIT B.

Agreement for water right in the Larimer County Ditch.

I. This agreement made this ——— day of ———, in the year 188—, between the Larimer County Ditch Company, a corporation existing under the laws of Colorado, as the first party, and ———, of the county of ——— and State of ———, as the second party, witnesseth:

II. That in consideration of the stipulations herein contained and the payments to be made as hereinafter specified, the first party hereby agrees to sell unto the second party ——— water right— to the use of water flowing through the ditch of said company, each water right representing one six-hundredth part of the capacity

of said ditch (less an amount from such total capacity sufficient to water 80 acres), subject to the terms and conditions herein specified, to which the said second party, — heirs or assigns, hereby expressly agree.

III. Said company agrees to continue said ditch on a suitable grade to a point not less than 6 miles on the line of said ditch after crossing Box Elder Creek, having a width on the bottom of not less than 10 feet, and a depth of not less than 4 feet from bottom to top of lower bank, such extension to be completed on or before May 15, 1883.

IV. Said company agrees to incur all the expense of building said ditch and extension, of the dimensions hereinbefore specified, without any assessment on purchasers of water rights for such purpose.

V. Said company will enlarge said ditch and its extension when it shall deem expedient.

VI. Said company agrees to furnish said water to the second party, — heirs or assigns, continuously during the irrigating season, except as hereinafter provided, and at no other time.

VII. Said water shall be used only for domestic purposes, and to irrigate the following described tract of land, and none other, to wit:

VIII. Under no circumstances shall said water or any portion thereof be used for mining, milling, or mechanical power, or for any purpose not directly connected with or incidental to the purposes first herein mentioned.

IX. Said second party, — heirs, or assigns, shall not permit said water, or any portion thereof, furnished as aforesaid, to run to waste, but as soon as a sufficient quantity shall have been used for the purpose herein allowed and contracted for, the second party, — heirs, or assigns, shall shut off said water, and keep the same shut and turned off until the same shall be again needed for the purposes aforesaid; but in no case shall the amount of said water taken or received by the second party, — heirs or assigns, exceed the quantity hereby sold.

X. Said company shall deliver said water at such point along the line of the said ditch, or from any of its reservoirs, either or all, as it may determine from time to time to be the most practicable, and all headgates, and the manner of withdrawing and regulating the supply of water from said company's ditch and reservoirs, shall be prescribed by the said company, and shall at all times be under its control as determined and directed by the board of trustees of said company.

XI. The headgate or gates through which the water hereby sold shall be drawn off shall be made and placed by said company, and the cost thereof, and for keeping the same in repair, shall be paid for by the said second party, and be collected and enforced in the same manner as prescribed for collecting and enforcing assessments.

XII. Said company agrees to keep and maintain said ditch and any and all of its reservoirs in good order and condition, and in case of accident to the same to repair the injury occasioned by said accident as soon as practicable and expedient; and the company shall have a right to assess for said maintenance, and the cost of enlarging said ditch, and enlarging any and all reservoirs, either owned or operated by it, and repairing, maintaining, and superintending the same, a sum equal to one six-hundredth part per water right sold of such cost, per annum, and the amount, manner of collection, and time of payment of said assessments shall be determined by said company according to its judgment and discretion; and the company also reserves to itself the right to establish and enforce such rules and regulations, and to provide and declare such penalties and forfeitures as it may

deem necessary or expedient for the purpose of enforcing and collecting said assessment, or any part thereof.

XIII. When said company shall have sold, and have outstanding and in force, 600 water rights, of a size and amount each as specified herein (or sooner, at the option of the company), it will then issue and deliver to the holder of each water right, who shall have complied with the terms and conditions of this contract, without further consideration, one share of the stock of said company and also one share of the stock of the Larimer County Reservoir Company for every water right hereby sold, which the second party, — heirs or assigns, hereby agree to accept.

XIV. Said company shall have the right to distribute such water as may flow through said ditch (less said amount sufficient to irrigate 80 acres) to the holders of such water rights, pro rata, and for the purpose of so doing may establish and enforce such rules and regulations as it may deem necessary or expedient.

XV. And the second party for ——— and ——— heirs and assigns agree—in consideration aforesaid, to waive, and hereby does waive any claim for loss or damage by reason of any leakage or overflow of said ditch, or any of its reservoirs, lakes, or laterals, either upon the land aforesaid or any other tract belonging to said second party or ——— assigns, anything in any statute, law, or custom to the contrary notwithstanding.

XVI. In consideration whereof the second party agrees to pay unto the first party the sum of ——— dollars, with interest, payable annually, at the rate of 12 per cent per annum, at the office of the first party in Fort Collins, Colo., in ——— payments, at the times and in the manner following, that is to say:

	Day.	Month.	Year.	Principal.	Interest.	Amount.	Remarks.
First payment.....							
Second payment.....							
Third payment.....							
Fourth payment.....							
Fifth payment.....							

And the second party, in consideration of the premises, hereby agrees that ——— will make punctual payment of the above sums as each of the same, respectively, becomes due, and that ——— will regularly and seasonably pay all assessments that may hereafter be imposed by said company for the purposes aforesaid.

XVII. And it is hereby agreed and covenanted by the parties hereto that time and punctuality are material and essential ingredients to this contract. And in case the second party shall fail to make the payments aforesaid, and each of them punctually, and upon the strict terms and times above limited, and likewise to observe, perform, and complete all and each of said agreements and stipulations aforesaid, strictly and literally, without any failure or default, then this contract, so far as it may bind said first party, shall become utterly null and void, and all rights and interests hereby created or then existing in favor of the second party, or derived from ———, shall utterly cease and determine, and all equitable and legal interest in the water right hereby contracted to be conveyed shall revert to and revest in said first party, without any declaration of forfeiture, or any other act of said first party to be performed, and without any right of said second party of reclamation or compensation for moneys paid or services performed, as absolutely, fully, and perfectly as if this contract had never been made. And it is further stipulated that no assignment of the premises shall be valid unless the same shall be indorsed hereon, and that no agreements or conditions or relations between the second party and ——— assignee, or any other person acquiring title or interest from or through ——— shall preclude the first party from the right to convey the premises to the second party, or ——— assigns, on the surrender of this

agreement and the payment of the unpaid portion of the purchase money which may be due the first party.

XVIII. It is further expressly understood and agreed between the parties hereto that neither this contract nor any of its terms, conditions, or provisions shall be in any manner supplemented, altered, or changed from what has been provided, or any other or further contract be made respecting the subject-matter of this contract, except that it be indorsed hereon in writing, signed by the president and attested by the secretary, under the corporate seal of said company.

XIX. It is also stipulated and agreed that from and after the execution hereof the said second party may enter into the use and enjoyment of the water flowing through said ditch to the extent of the right above contracted to be conveyed, as fully as though a final certificate for said right had been issued, but subject, nevertheless, to all the terms and conditions above set forth.

XX. In witness whereof the Larimer County Ditch Company has caused its corporate name to be hereunto subscribed by its president, and its corporate seal to be hereunto affixed by its secretary, as well as to a duplicate hereof, and the second party — subscribed — name — and affixed — seal — hereto, as well as to a duplicate hereof, the day and year first above written.

By _____,
 _____, *President.*
 _____, [SEAL.]
 _____, [SEAL.]

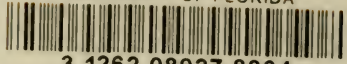
Attested by—

_____, *Secretary.*

[Forms for assignment and for acknowledging receipt of each payment are printed on the reverse side.]



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